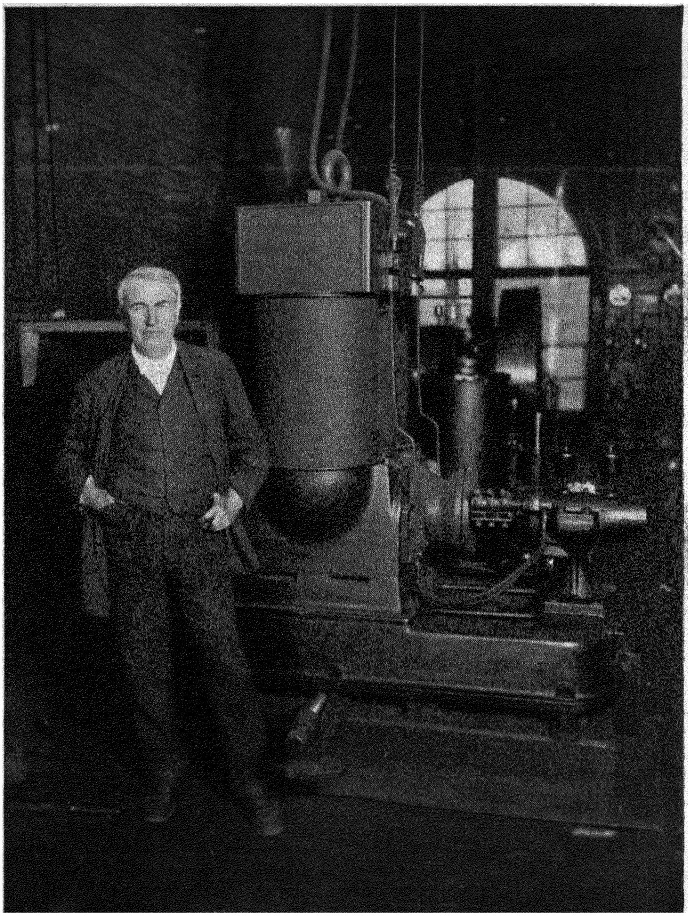
Bryan. George.

Edison

Edison: The Man and His Work



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EDISON AND HIS FIRST INCANDESCENT-LIGHTING DYNAMO

EDISON

THE MAN AND HIS WORK

by

GEORGE S. BRYAN

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MANUFACTURED IN GREAT BRITAIN

PREFACE

The ending of the Civil War released American energies for activities of peace. Then followed the era during which industries in the United States were transformed and public utilities were organized and developed. It was a time when mingled with so much that was convenient, serviceable, and beneficial went ruthless financial piracy and the sorriest alliances between politics and "big business." In those crowded decades, pure science—the disinterested search after truth for its own sake—was even less emphasized than now in our "practical" land. On the other hand, an essential part was naturally played by workers in applied science. Their inventions made possible the growth of forces destined to have vast effect upon the country's political, economic, and social life.

Among such men, Edison, by his directed good sense, patient resourcefulness, repeated conquest of obstacles, and varied achievements, won in the general mind a place of especial distinction—a place that he continued to hold after he had left Menlo Park and entered upon a new phase of his career. Interest was unfailing, too, in the human side of the man—his beginnings, his early struggles, his capacity for toil, his working methods, his distinctive personality, his simple ways, his blunt opinions—even his prejudices.

In the course of a half-century, a great quantity of material relating to Edison has been printed; but a goodly part of it is more or less inaccessible to the ordinary

reader, and a surprisingly large amount of it is superficial, inaccurate, misleading. Dyer and Martin's valuable "Life" is a two-volume work and was issued so far back as 1910. The fact is that to-day many persons, though they accept Edison as among eminent Americans, have but vague and erroneous ideas regarding either the man or his actual achievement. To a certain extent, therefore, this present book is its own excuse for being. It brings the story of Edison down to date and within moderate compass; and it endeavors to present afresh the main features of that story in clear, readable narrative. It recognizes, and would do full justice to, the human interest inherent in its subject; but at the same time it assumes that Edison cannot properly be separated from his work. Hence it seeks to explain that work—not elaborately nor learnedly but accurately, with sufficient fulness, and in non-technical language. It further aims to avoid the irresponsible mythology and the rather indiscriminate panegyric that have at times done disservice to Edison's right fame.

It is at least based on independent research that included not only a survey of the available literature but also the privilege of special sources—personal inquiry having met with friendly aid. The Dyer and Martin "Life" has, of course, been frequently consulted, especially for Edison's own words; and due credit has been given *passim.* Among those to whom the author would acknowledge particular indebtedness are: the late George Kennan, well-known author and publicist; Maj. William J. Hammer, one of Edison's trusted associates in the Menlo Park days and later distinguished as a consulting electrical engineer; Mr. Arthur Williams, general commercial manager of the New York Edison company; Mr.

George Iles, authority on American invention; the librarians of the United Engineering Society (New York); and Dr. Herbert Putnam of the Library of Congress, where every facility was most helpfully placed at my disposal.

G. S. B.

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EDISON

I

PRELIMINARIES AND BEGINNINGS

THE earliest Edisons in the United States came directly from Holland. About 1730 they landed on American soil at Elizabethport, the part of Elizabeth, New Jersey, that lies along Staten Island Sound. Thence they went inland a few miles, to the small village of Caldwell, where they settled and prospered. It is as the birthplace of Grover Cleveland, twice president of the United States, that Caldwell is perhaps best known.

Great age seems to have been somewhat common among the Edisons; and a Thomas Edison reached one hundred and four years. In the days of the American Revolution, this Thomas was stoutly for the Continental cause, and John, Thomas' son, was as stoutly a Loyalist. After the Revolution, John, like many other Loyalists, emigrated to Canada; first to Nova Scotia, then in 1811 by ox-team, pioneer-fashion, to Bayfield in Upper Canada, as Ontario was at that time called. In order to attract Loyalist settlers into Upper Canada, the British government was making liberal grants of land. John Edison received a tract of six hundred acres and went to occupy it. Later, he removed again—this time to a place named Vienna, near the northern shore of Lake Erie.

In Vienna, Samuel, son of John, set up for himself as a hotel-keeper. Prior to this, little is known of Samuel, save that he was born in 1804 in Digby, a seaport town of Nova Scotia. He married in 1828 a Miss Nancy

Elliott, an eighteen-year-old teacher in the Vienna high-school and daughter of the Rev. John Elliott, a Baptist clergyman of Scots descent. John Edison remained at Vienna until he died at the age of a hundred and two. Samuel sought the United States—rather from necessity, however, than of deliberate choice.

William Lyon Mackenzie, a Canadian politician, was rightly enough convinced that the government of Upper Canada was much in need of reforms. He organized an unsuccessful attempt to obtain these reforms by force. When he tried to seize the lieutenant-governor and set up a provisional government, it turned out that his plans had been so poorly made and his supporters were so few that the movement was utterly a failure. Samuel Edison, six feet and of strong physique, was a captain of Mackenzie's insurgents; and when Mackenzie fled across the border to the States, Samuel Edison followed his leader's example. One story has it that, in his eagerness to escape, he made a forced journey of more than a hundred and eighty miles, with little of either food or sleep. If the story be true, this flight of Samuel Edison suggests a comparison in some ways with that famous trip of Daniel Boone, when, having escaped from the Shawnees, he travelled through one hundred and sixty miles of forest in four days, during which he ate but one meal. Knowing that his Canadian property would now be forfeit to the government against which he had revolted, Samuel Edison looked for a likely spot in which to establish a new home, and at last found it, in 1842, in Milan, Ohio.

To-day Milan, trim, shaded, comfortable, is for all the world like many another hamlet in that part of the state. It has a public square, a soldiers' monument, and tidy houses set in ample grounds. It claims no important industries. and treasures but one mark of distinction.

When Samuel Edison made up his mind to settle there, things were different. Milan was then flourishing, and had prospects of a large development in trade. Its location seemed to promise for it a distinct future. In Ohio were then no railways to carry eastward the wheat from productive fields. The Huron river furnished for northern Ohio a natural outlet to Lake Erie; and Milan was on the Huron, not far from the lake. True, the river was not navigable for all of the way to the town; but that difficulty was solved by the building of a short canal to connect Milan with the head of navigation at Lockwood Landing. At the canal-side in Milan rude warehouses were built. Grain to fill them poured in from the surrounding country in four-horse and six-horse wagon-loads. The canal would float sailing-vessels up to two hundred and fifty tons' burden, and as many as twenty such vessels were laden in a day at Milan with cargoes of wheat. Shipbuilding and various other industries were started. The place was busy. It seemed to Samuel Edison that he had made a sensible choice. He set up a workshop where he made hand-wrought shingles; and for his stout, durable product the demand was so large in that region that in time he employed several men.

In Milan during this its flourishing period, Thomas Alva Edison was born—on February 11th, 1847; and there he passed his first seven years. It might be well to explain that the name Alva was bestowed in honor not of the notorious Duke of Alva, who vainly tried to subdue the Dutch, but of a Capt. Alva Bradley, who owned numerous vessels plying on the Great Lakes and was a friend of Samuel Edison's. The Edison house, a substantial-looking brick cottage, is yet standing, almost unchanged, and townsfolk point it out to visitors.[1]

[1] It has more than once been curiously alleged that Edison is of

The same Thomas Alva who in later years became known as one that could endure, apparently without fatigue, an uncommon amount of continuous and exacting application to hard work, looked, when a very small boy, somewhat frail, and was thought to be hardly strong enough to attend school. He is presented to us as a rather grave, old-fashioned child, occupied with little constructive tasks or asking questions with a solemn persistence. His was a mind that already was observing and investigating. Of the many anecdotes of that period, one says that he had taken notice of a goose sitting on some eggs, and afterward of the goslings running about. Then followed a day when he vanished. After lengthy search, he was discovered in the barn, sitting on a collection of hen's eggs and goose eggs that he seemed to be hopeful of hatching.

Yet the escapades and hairbreadth escapes of enterprising boyhood were his, too. In one of the Milan warehouses he tumbled into a great pile of wheat and was almost smothered before he could be got out. Once he held a skate-strap for another lad, who was trying to shorten it by means of an axe; the chief result being that Edison lost the tip of a finger. At another time he came close to drowning in the canal. But perhaps his most thrilling experience arose through his inspiration to build a fire in somebody's barn. The barn was speedily burned, and he was duly whipped—not in the seclusion of the woodshed but before the general gaze in the public square. Such things were all in the day's adventures. Edison

Aztec origin. In the "New York Tribune" of March 13, 1923, appeared an abstract of a fantastic story to that effect that, so it was stated, was published on March 12 in a newspaper of Mexico City. In connection therewith the "Tribune" added that W. H. Meadowcroft, Edison's personal representative, had said that "he knew of no foundation in fact."

had a sister, Tannie (afterward Mrs. Bailey), and a brother, William; but of them we scarcely hear, and they do not appear to have played any particular part in his development.

Thus life ran along. Then something happened to Milan. Railway promoters had endeavored to negotiate with local capitalists, but the capitalists, relying upon their canal, preferred that the new-fangled carrier should not enter the town. It was not long before Milan became aware that railways were factors to be reckoned with in Ohio; and next, that its "boom" had departed. Grain shipments were sent from neighboring towns by rail, and Milan ceased to be a center of the wheat trade. Of the canal, nothing now remains but a depression in the earth, so concealed by vegetable-gardens or overgrown with grass as scarcely to be traceable along the valley. It may be added that the wholesale throttling of canals by railway interests was not at all fortunate for the country at large. A great deal of non-perishable freight could always have been shipped quite as satisfactorily and much more cheaply by water routes.

Again Samuel Edison began to seek a location for a new home. In 1854 he went to Port Huron in Saint Clair county, Michigan, where he became a dealer in feed and grain and also engaged in the lumber business. Port Huron is at the lower end of Lake Huron, at the junction of the Black and Saint Clair rivers. Three years after Samuel Edison had arrived there, it received a city charter. It was thriving, and Samuel Edison throve reasonably with it.

II

THE YOUNG EXPERIMENTER

AT Port Huron Edison went to school for three months. That was all the formal education he ever received. He afterward described himself as pretty consistently at the foot of his class. To an inspector his teacher reported him as "addled." It may be of interest to note that Sir Isaac Newton, when a lad, was considered rather a dunce; that James Watt, the inventor of the modern condensing steam-engine, stood poorly in his classes; and that regarding Sir Humphry Davy, the eminent English chemist, one of his teachers later declared, "While he was with me I could not discern the faculties by which he was so much distinguished." Time proved their quality, as it did Edison's.

Edison's mother is portrayed as capable, well-informed, and of not a little culture. Her own experience as a school-teacher had not given her a very high opinion of the public schools of her place and day. She sharply resented the notion that "Al"—as family and friends called him—was addled; in fact, she was inclined (with, perhaps, a natural touch of prejudice) to believe his mind was beyond the ordinary. She undertook, therefore, to teach him the rudiments in her own way, and to guide his general reading. Before he was twelve he had gone through such solid works as Gibbon's "Decline and Fall of the Roman Empire" and Hume's "History of England." Fiction does not appear to have had much of a place on

the schedule. Samuel Edison paid the boy a small sum each time the contents of a book like these had been grappled with and conquered. Teacher and pupil made a joint attack on Newton's "Principia"; but, as might have been expected, this proved to be quite too tough a morsel for both. Edison was never proficient in mathematics. In after years, his researches frequently involved elaborate calculations; and for these he was forced to depend mainly upon the labors of associates.

Although not a mathematician, he was naturally an experimenter. In the egg incident had been revealed a turn of mind that now found further expression. A Dutch youth, Michael Oates by name, was employed as the family chore-boy. To test a theory that gases so generated might enable a person to fly, Edison induced Michael Oates to swallow a large quantity of Seidlitz powders. Far from flying, however, Michael developed pains that compelled general attention. Truth was shortly out; and the young experimentalist suffered an application of a switch kept for emergency purposes behind the clock. After that, he obtained a copy of Parker's "School Philosophy," then in considerable use as a text-book in elementary physics; and few were the experiments outlined in it that he did not try. Then and afterward it was characteristic of him to challenge and test statements that he encountered in his reading in natural science.

In the cellar of the house he assembled materials for his first laboratory. Among these were two hundred bottles, carefully arranged on shelves and all labeled POISON. "My mother's ideas and mine differed at times," he once said, "especially when I got experimenting and mussed up things." Indeed, Mrs. Edison ordered the removal of the laboratory—two hundred bottles and all; but she finally compromised the matter by allowing the "mess" to

continue, provided it was kept under lock when "Al" was absent. Most of Edison's pocket-money went to buy such chemicals as were to be had in the local drug-shops. An observer at that time might have anticipated that the lad would become an analytical chemist rather than a physicist. The chemical knowledge that Edison thus early began to acquire was subsequently of great service to him, especially in problems connected with his incandescent lamp and his storage-battery.

It was through the argument that he needed money to buy more chemicals that he won permission to apply for the concession to act as a newsboy on trains of the Grand Trunk railway line between Port Huron and Detroit, a round distance of one hundred and twenty-six miles. The concession once gained, he began working on an accommodation-train that left for Port Huron at seven in the morning and, on the return trip, reached there at nine-thirty in the evening. This was not, strictly speaking, his first business experience. With a horse and a small wagon, he and Michael Oates had peddled garden-truck raised on Samuel Edison's acres; and in one year $600 had been taken in and turned over to Mrs. Edison.

"After being on the train for several months," were Edison's own words, "I started two stores in Port Huron —one for periodicals, and the other for vegetables, butter, and berries in the season. These were attended by two boys who shared in the profits. The periodical store I soon closed, as the boy in charge could not be trusted. The vegetable store I kept up for nearly a year." Nor was this all. He obtained the privilege of installing a newsboy on an express-train leaving Detroit in the morning and returning at night. After a while, a daily immigrant train was run. "This train," Edison said, "generally had from seven to ten coaches, filled always with

Norwegians, all bound for Iowa and Minnesota. On these trains I employed a boy who sold bread, tobacco, and stick candy." Such were the mercantile enterprises of this lad of but a dozen years.

The Civil War lent so great a stimulus to Edison's newspaper sales that he gave up the vegetable store. Years afterward, he related an instance of his attempts to meet the demand for news. One day in 1862—presumably April 8th, he found crowds gathered in Detroit about the bulletin-boards of the various local papers. Reports had been posted that the battle of Shiloh (or Pittsburg Landing, as it sometimes has been called) had just been fought in Tennessee, with a total loss on both sides of 60,000 killed and wounded. (It was later learned that these figures were wildly exaggerated, and by historians the aggregate losses have been set at about 20,000.) At sight of those Detroit crowds, Edison had a sudden inspiration. He hurried to the Grand Trunk station, and there finally prevailed upon the telegraph operator to telegraph the rumor to Port Huron and all the stations along the route.

". . . He sent it," said Edison, "requesting the agents to display it on the blackboards used for stating the arrival and departure of trains. I decided that instead of the usual one hundred papers I could sell one thousand; but not having sufficient money to purchase that number, I determined in my desperation to see the editor himself and get credit." The editorial office to which he went was that of the "Detroit Free Press," a morning paper that later became quite widely known for humorous sketches written by C. B. Lewis and signed "M. Quad." "I was taken into an office where there were two men, and I stated what I had done about telegraphing, and that I wanted a thousand papers, but only had money for three hundred, and I wanted credit. One of the men re-

fused it, but the other told the first spokesman to let me have them. . . . By the aid of another boy I lugged the papers to the train and started folding them. The first station, called Utica, was a small one where I generally sold two papers. I saw a crowd ahead on the platform, and thought it some excursion, but the moment I landed there was a rush for me; then I realized that the telegraph was a great invention. I sold thirty-five papers there."

So it went at all the stations between Detroit and Port Huron. "It had been my practice at Port Huron," Edison explained, "to jump from the train at a point about one-fourth of a mile from the station, where the train generally slackened speed. I had drawn several loads of sand to this point to jump on, and had become quite expert. The little Dutch boy [Michael Oates, once more] with the horse met me at this point. When the wagon approached the outskirts of the town I was met by a large crowd. I then yelled: 'Twenty-five cents apiece, gentlemen: I haven't enough to go around!' I sold all out, and made what to me then was an immense sum of money."

Of Edison's daily takings, one dollar went regularly to his mother, but most of his profits he spent for chemicals and chemical apparatus. His experiments were now mainly conducted not in the cellar of the Edison house, but in his "laboratory on wheels." The baggage-car of the accommodation-train happened to be divided into three compartments: one for express-packages and baggage, one for United States mail, and one originally intended for smokers. The smokers' compartment remained unused; and Edison accordingly was permitted by the conductor to appropriate it. There he not only kept his stock of newspapers, magazines, candy, popped-corn balls, and other things, but also established a new workshop. An ever-increasing array of jars, batteries, bottles, test-

tubes, and other paraphernalia, was crowded into this; and in it was stored a surprising quantity of chemicals, which he now could obtain in Detroit to a much greater extent than had been possible in Port Huron. As a basis for his experiments Edison had a copy of a translation of a work on qualitative analysis by Karl Fresenius, a German professor. This treatise, and the same author's companion-work on quantitative analysis, had at one time a wide circulation. In the baggage-car, as it jarred and rocked, the young newsboy found odd moments for his studies. In passing, it may be mentioned that some of Edison's equipment was made for him by George M. Pullman, later known in connection with the manufacture of Pullman railway cars, who at that time had a little shop in Detroit.

Something else was to be found in that compartment of a Grand Trunk baggage-car: a diminutive printing-plant, whence issued "The Weekly Herald." Edison's observation of the popular demand for news led him to try newspaper publishing on his own account. Constantly in touch with the railway telegraph, he was often enabled by this means to chronicle local items that, if they reached the Detroit journals at all, would reach them long after. In Detroit he discovered and bought a small press that had been used for the printing of hotel menu-cards. There he also purchased types; and, with his natural mechanical facility, he soon learned the elements of type-setting and make-up. The price of "The Weekly Herald" was three cents a copy, or eight cents for a month's subscription. The circulation exceeded four hundred copies a month. Edison was the Pooh-Bah of the undertaking: reporter, editor, compositor, make-up man, pressman, devil, advertising manager, circulation manager, and news-agent. This unique paper must be con-

sidered remarkably well done, especially when regard is had to the age of the proprietor and editor, and to the unfavorable conditions under which the mechanical work was performed.

But Edison's energy and ingenuity sought yet further exercise. He became interested in electricity. According to his own account, this was "probably from visiting telegraph offices with a chum who had tastes similar to mine." This chum and he set up a telegraph-line between their homes. In those days, amateurs could not purchase electrical equipment and supplies as they may now. These lads were compelled to improvise everything they used. For their wire they had the sort of wire that was commonly used to support stove-pipes; for their insulators, bottles. The bottles were hung on nails driven into trees or, when no trees offered, into flimsy poles. Bits of spring brass served for keys, and rags insulated the magnet-wire. It is gravely stated that Edison, seeking to obtain current at the minimum cost, actually experimented with cats as a possible source of static electricity to be applied to the "line." In these experiments the cats absolutely declined to assist; but the line was made to work by batteries in the conventional way.

As has been said earlier in this chapter, Edison did not reach Port Huron on his return-trip until nine-thirty in the evening. His bedtime was fixed by his father at eleven-thirty. This arrangement did not leave much chance for practice in telegraphy, and so Edison's inventiveness was called into play. He had been accustomed to take home each evening his unsold stock of newspapers; and each evening Samuel Edison would look over this handy supply of reading-matter. With some plausible excuse for so doing, Edison now left the "returnables" with his chum; but he intimated that he still could get the

news for his father over the "private wire." Interested to see how this might be done, Samuel Edison assented to the plan. The chum sent messages which Edison received and wrote out in long-hand; and so absorbed was the father in reading them that it was sometimes one o'clock of the next morning before he and "Al" turned in. The eleven-thirty rule was officially rescinded; the unsold stock of papers was again brought home; and Edison and his coöperator continued their practice until both were fairly versed in the first principles of electric telegraphy. A roaming cow happened to get entangled in the line, and sadly damaged it. It seems not to have been replaced; but it had been the means by which Edison had made a beginning in a field of work in which eventually he had few equals.

The travelling printing-office and the rolling laboratory had meanwhile flourished; but one day mischance more serious than a roaming cow befell them. The train was running at a smart speed over a stretch of badly-laid track—a great deal of track was badly-laid in that period of American railroading. The baggage-car lurched. In Edison's compartment a phosphorus stick was thrown from a shelf to the floor. Ignited by the friction, the phosphorus blazed up with the intense whitish light peculiar to that substance when burning. The car took fire; and Edison, rather frightened, started to fight the flames. Then in rushed the conductor with some water, and the car was quickly saved. The conductor had, however, lost his head and his temper. It had been with his knowledge and consent that Edison was long permitted to experiment with chemicals on a moving train. He knew that the boy had always treated the privilege with respect and had always been careful. He should have realized that the fire was the result of an accident. Yet now, in

unreasoning rage, he violently cuffed Edison's ears; and at the Mount Clemens station he ejected Edison and Edison's entire outfit—laboratory, printing-plant, and all—and left them on the platform: the outfit in ruins, the boy in tears.

From the brutal blows of this "rattled" conductor came the deafness that remained with Edison through life. He once said that he thought deafness had been of great advantage to him "in various ways"; and he went on to specify how it acted to protect him from external distractions, and to spur him to further effort in the development of the carbon transmitter for the Bell telephone, and in the perfecting of the phonograph. While admiring his spirit of philosophical acceptance, one may at the same time regret that ignorance, carelessness, or force is able to injure or destroy persons of value in the world; that a great President is murdered by a wild-brained partisan, a distinguished scientist killed by a drayman, a youthful Edison permanently afflicted by an inconsequential employee.

After this experience, Edison restored his laboratory to the home cellar; having first, however, promised that he would not bring into it anything dangerous. The printing-plant, also, he transferred to the house. No further accidents occurred; and the publication of "The Weekly Herald" went successfully along until Edison, at the suggestion of a young friend, enlarged the paper, which he renamed "Paul Pry," and which, in accordance with its new title, was mainly devoted to Port Huron gossip and personalities. Mannerisms and peculiarities of local individuals were dealt with rather freely. One victim was so annoyed that he pitched the editor and publisher into the Saint Clair river. Not long afterward, the paper ceased to be issued. For newspaper work Edison

had a pronounced liking, but his career was destined to run in other channels.

When in Detroit between trains, he usually spent considerable time in the public library. His reading was not limited strictly to chemistry. Indeed, when he began he was so liberal and inclusive that he tackled a complete section and tried to go through it shelf by shelf in a whole-hearted onslaught upon knowledge.

Hardly less attractive than the Detroit public library were the Port Huron machine-shops of the Grand Trunk. Sometimes a friendly engineer let him ride in the cab, or even pilot the locomotive for a short distance. Of an experience as engineer, Edison once gave an amusing description. The locomotive had, he said, after the custom of the time, "bright brass bands all over, the woodwork beautifully painted, and everything highly polished." . . . The train, it seems, was a slow freight; and the preceding night, engineer and fireman had attended a dance given by a railroad men's fraternal organization. "After running about fifteen miles they became so sleepy that they couldn't keep their eyes open, and agreed to permit me to run the engine. . . . I was greatly worried about the water, and I knew that if it got low the boiler was likely to explode. I hadn't gone twenty miles before black, damp mud blew out of the stack and covered every part of the engine, including myself. . . . Then I approached a station where the fireman always went out to the cowcatcher, opened the oil-cup on the steam-chest, and poured oil in. I started to carry out the procedure, when, upon opening the oil-cup, the steam rushed out with a tremendous noise, nearly knocking me off the engine. I succeeded in closing the oil-cup and got back in the cab, and made up my mind that she would pull through with-

out oil. I learned afterward that the engineer always shut off steam when the fireman went to oil. . . . My powers of observation were very much improved after this occurrence." Before he had reached his destination, a second deluge of mud took place. He then discovered that he had been carrying not too little water, but so much that it had passed over into the stack and dislodged a mass of accumulated soot. He did not persist in the study of steam-engineering practice, but in later years was a pioneer in the development of the electric locomotive.

Now and then some prank enlivened Edison's busy hours. One of these had to do with a practical joke played upon the sentries at Fort Gratiot. This old army post, close to the village of Port Huron, had been abandoned in 1852; but after the outbreak of the Civil War, volunteers were quartered there. Edison and his Man Friday, Michael Oates, had often at night been hearing a call passed along the line of sentries, ordering out the corporal of the guard. So, one very dark night, in tones as nearly stentorian as he was able to manage, Edison imitated this call. "The second sentry, thinking it was the terminal sentry who shouted, repeated it to the third, and so on. This brought the corporal along the half mile, only to find that he was fooled. We tried him three nights; but the third night they were watching, and caught the little Dutch boy, took him to the lock-up at the fort, and shut him up. They chased me to the house. I rushed for the cellar. In one small compartment, where there were two barrels of potatoes and a third one nearly empty, I poured these remnants into the other barrels, sat down, and pulled the empty barrel over my head, bottom up. The soldiers had awakened my father, and they were searching for me with candles and lanterns. The cor-

poral was absolutely certain I came into the cellar, and couldn't see how I could have gotten out, and wanted to know from my father if there was no secret hiding-place. On assurance of my father, who said that there was not, he said it was most extraordinary. I was glad when they left, as I was cramped, and the potatoes that had been in the barrel were rotten and violently offensive." Next morning Michael Oates was released. After that, Edison probably interfered no further in military affairs.

It was during Edison's newsboy period that the Prince of Wales (afterward Edward VII), as "Lord Renfrew," visited the United States and Canada. At Sarnia, opposite Port Huron on the Ontario side of the Saint Clair river, elaborate preparations were made for a public reception of the Prince; and Edison, with most other Port Huron lads, went over to attend. "Several of us expressed our belief that a prince wasn't much, after all, and said that we were thoroughly disappointed. . . . Soon the Canuck boys attacked the Yankee boys, and we were all badly licked. I, myself, got a black eye." Once (it was about a week before Christmas, and apparently Edison had laid in a special holiday stock) Edison's train jumped the track. Four ancient cars, with rotted sills, were quickly smashed into kindling-wood, and over the right-of-way were spread Edison's raisins, dates, figs, and candies. To prevent what looked to him like deplorable waste, Edison tried eating the scattered supplies. "Our family doctor," he commented, "had the time of his life with me."

III

A START AT THE KEY

It was at the Mount Clemens station that the flustered conductor threw out Edison, laboratory, and printing-outfit. Another incident, an incident that was to have an important bearing upon the newsboy's later career, also occurred there.

One morning of August, 1862, Edison stood on the Mount Clemens platform, waiting while the "mixed" on which he worked did a half-hour's switching of freight cars. A loaded box car, with no brakeman aboard, had just been shunted from a siding to the main track, along which it was now rolling at a considerable speed. Suddenly Edison noticed a child playing in the gravel ballast of the line. In a glance he recognized the little son of J. U. Mackenzie, the station-agent. Tossing his cap aside and dropping his bundle of papers, he dashed out upon the track. Not a second too soon was he, for one of the car-wheels struck his heel as he swung the child to safety.

Mackenzie, who already knew and liked Edison, gratefully offered to instruct him in train telegraphy. The offer was quickly accepted. As we have seen, Edison was before that pretty familiar with the Morse code. When he began his study with Mackenzie, he carried to Mount Clemens a trim set of telegraph instruments that he himself had made in a Detroit gun-shop. He at once di-

vided his "run," assigning to a friend the portion between Mount Clemens and Detroit.

The instructor found that his teaching could be confined in large part to the special signals used by railway operators in facilitating their work. These signals included various symbolic numerals. It may be of interest to know, for example, that the railway telegrapher's symbol to indicate a message of accident or death, was "23"; and that this was the real source of an expression once common in popular slang, with the general meaning of "bad luck." Shortly after Edison had begun this study, came the forcible termination of his activities as newsboy; and then he was able to devote to telegraphy as much as eighteen hours a day. He had by this time a strong physique and uncommon powers of endurance, so characteristic of him in later life. In about four months the pupil had gained all that the teacher could impart. He now definitely entered a field in which he was to know a half-dozen years of toil, but in which he also was to have abundant chance of observation and experiment; becoming increasingly skilled in that electrical science wherein he attained what have been considered his finest achievements.[1]

[1] As illustrative of the legends that have so profusely collected around Edison, may be instanced that concerning the telegrapher Ward. On September 9, 1923, the "New York Times" printed the following item: "TAUGHT EDISON MORSE KEY. Joseph C. Ward, Called Oldest Telegrapher, Dies at 79. Visalia, Cal., Sept. 8.—Joseph Clarence Ward, 79, a telegrapher at General Grant's headquarters during the Civil War, and the man credited with having taught Thomas A. Edison the Morse code, died here yesterday." To this had been added in the newspaper office this paragraph: "When the telegraph company for which he worked closed its Visalia office, Ward retired, after sixty years at a telegraph key. He was then spoken of as the oldest operator in the country. He was stationed at Mount Clemens, Mich., when Thomas A. Edison was a newsboy on trains passing there.

He first strung a telegraph line from the Port Huron station to the village, about a mile away, and there opened in a drug-shop a little office of his own. The regular office was, however, amply sufficient to take care of village business; and his venture soon was ended. Before long, he became the operator in the regular office, which had quarters in Walker's jewelry-store. Walker was a kind of small-town factotum, who not only sold jewelry and directed the local telegraph-office, but traded, too, in newspapers and magazines. Edison slept on the premises, so that he might be ready for emergency night-calls. He liked this arrangement because at night, and well along into the earlier morning hours, newspaper dispatches (or "press report," as operators called them) were passing over one of the wires. Edison, always eager to become more adept, would "cut in" and copy, as well as he might, these dispatches, which were more difficult to manage than the routine commercial messages. This he found to be excellent practice. All the more ambitious operators in those days hoped to qualify to "take press."

The office was not a very busy one; but even so, out-

Edison spent his spare hours in Ward's office and learned the code from him." Previous to this, "Collier's" had had an editorial article about "J. E. Ward," in which it said: "As the world is prone to judge men, Ward did not climb to the top rung of success in his calling. Yet that kindly, faithful operator had a lot to do with the success of one of our most beloved Americans. Years ago, when Ward was stationed at Mount Clemens, Mich., he spent ten or fifteen minutes every day patiently teaching a tow-haired boy the Morse code. That boy, one Thomas A. Edison, has done first-rate since then."

Doubtful of the Ward story, the present writer sent a query to W. H. Meadowcroft, long Edison's assistant, who kindly obtained from Edison this authoritative reply: "There is no foundation for the statement. J. U. Mackenzie taught me telegraphy. Ward was a relative of Mackenzie's wife. He was a military telegrapher in the Civil War and spent one vacation at Mackenzie's. He never taught me."

going messages might often have been seen hanging unsent upon a hook, while the operator was in Walker's cellar, engrossed in a chemical experiment; or in the drug-shop, buying a fresh supply of materials. Walker afterwards described young Edison as quite likely to seize from the watch-repairer's table any tool that he thought might be suited to his immediate purpose. Even then, Edison labored intensely toward his goal. Once an experiment had been completed, once a statement had been verified or a theory tested, tangles of wire and groups of jars might be indiscriminately left and forgotten. The "Scientific American" was then in existence, having been established as far back as 1845; and it formed part of Edison's favorite reading.

After a while, Edison applied for a job on the Grand Trunk, and obtained the post of night operator at Stratford Junction, Ontario. He was now a full-fledged operator. The year was 1863, and his age was sixteen. At Stratford Junction, Edison made his first invention. His hours of duty were from 7 P. M. to 7 A. M.; and a regulation was that from 9 P. M. he was to send each hour the signal "6" to the office of the train dispatcher. This was called "sixing," and was taken as circumstantial evidence that the operator was awake. Hourly each night came the signal from "Sf," as Stratford Junction was known; yet it began to be noticed that, strangely enough, a train message sent to "Sf" almost immediately afterward often failed utterly to bring a response. Investigation revealed the cause. Edison, devoting the greater part of his days to research, felt the need of sleep at night, and had therefore devised and put into action an ingenious contrivance. To both the telegraph line and a clock he attached a wheel with a notched rim. When the line was quiet, the clock was started. On each hour the wheel automatically re-

volved and sent the necessary dots. The mechanism of the familiar district-messenger call-box is somewhat similar. Whatever may have been private opinion as to his ingenuity, Edison received an official reprimand.

Within a short time thereafter, Edison left Canada in a hurry. "One night," was his version of the episode, "I got an order to hold a freight train, and I replied that I would. I rushed out to find the signalman, but before I could find him and get the signal set the train ran past. I ran to the telegraph office, and reported that I could not hold her." In the meantime the dispatcher had permitted the train bound in the opposite direction to leave the next station. "There was a lower station near the junction, where the day operator slept. I started for it on foot. The night was dark, and I fell into a culvert and was knocked senseless." This truly melodramatic situation was resolved by the fact that the alert engineers of the respective trains brought them to a halt in time to avert an accident. All the same, and in spite of the whole thing having occurred through no fault of his, Edison was summoned to Toronto to appear before the general manager. During the course of the inquiry, visitors temporarily claimed the manager's attention; and at this lull in the proceedings, Edison decided to slip from the room. At the Grand Trunk freight station he found a conductor with whom he was acquainted and who was about to take a freight train to Sarnia. He got a ride to Sarnia on the freight train, and the ferry landed him upon Michigan soil. Then he felt somewhat relieved. He did not return to Canada; but neither did he relinquish telegraphy.

IV

A "LIGHTNING-SLINGER" IN THE MID-WEST

AFTER a short stay in Port Huron, Edison entered the employ of the Lake Shore and Michigan Southern railway as night operator in the division superintendent's office at Adrian, a small city in the south-eastern corner of Michigan. Thus a new chapter of his life began. For about five years he was a roving "knight of the key."

On May 24th, 1844—less than twenty years before—the electro-magnetic telegraph system invented by Samuel F. B. Morse had first been commercially tried on a large scale. The extension of the new art of telegraphy opened to aspiring young fellows a constantly widening field. The operator's craft was viewed as affording an apprenticeship that, attractive in itself, might well lead to larger things. Such men as Andrew Carnegie, George Kennan, and Sir William Van Horne were operators in those early days, as were many others afterward prominent. A goodly number of telegraphers later became officials of American railway systems.

When the Civil War broke out, hundreds of operators were summoned to the military telegraph services of the respective forces. In the Federal armies alone, it is said, about 1,500 men were on an average detailed for duty as military telegraphers at the front. These men were usually of a very skilful, resourceful, and dependable sort. At the beginning of the fifty-first chapter of his "Personal

Memoirs,"[1] General Grant explains how the field telegraph was set up and communication effected between all the headquarters. Paying tribute to the telegraph corps, he says: "Nothing could be more complete than the organization and discipline of this body of brave and intelligent men."

Other operators enlisted in the ranks on one side or the other. Hence, as a natural result of war conditions, the supply of operators for the purposes of civil life, practically everywhere throughout the North, was unequal to the demand. At the time when Edison took the position in Adrian, telegraph offices in important centers were likely to be understaffed, and in such places an itinerant operator might pretty safely count on getting a desk. It is probable that at the close of the war the majority of the surviving operators of the military telegraph corps returned to the peaceful practice of their calling. New factors, however, for a time promoted a continued demand. Prominent among these were the development of manufacturing, and of industrial enterprises generally, in the East; and the new construction of railways in the West. Both commercial and railway telegraphy thus received fresh impetus. This state of affairs existed to a considerable degree until about 1876, when the newly invented telephone began to hint its possibilities.

The growth of telephone service was far more rapid in the United States than in any other country of the world. This growth (which, as will later be seen, owed much to Edison's aid) acted as a backset to telegraphy, which already had felt the effects of the decline in commerce and in railway-building, following the financial crisis of 1873. The telegraphic field now offered fewer inducements to ambitious or adventurous spirits. Conditions within it

[1] Vol. II, pp. 204–208.

tended to become more and more stabilized, and operators were increasingly available for existing vacancies. In the meantime Edison completed his years of roving and entered upon yet another stage of his career.

During those years he went from Adrian to Fort Wayne, Indiana, and to Indianapolis; thence successively to Cincinnati, Memphis, and Louisville; northward to Detroit, back to Louisville, southward to New Orleans; again to Louisville and to Cincinnati, where he did not remain long; and after a vacation interim at Port Huron, away to Boston.[2] Therefore, before he came east to what was to be his final job as an operator, he had travelled widely over the Central States and had held positions in five of them. When he went to Indianapolis, he entered the service of the Western Union Telegraph company, and after that he was not again in railway employ.

To be sure, by 1864, when Edison began at Adrian, the telegraph was a firmly-established utility. For the year ending June 30th, 1868, the Western Union company alone reported 3,219 offices; 50,183 miles of line; and 97,594 miles of wire. Telegraphic apparatus and equipment had passed beyond the extreme crudity of their earliest years. Yet, on Edison's own authority, many of the wires in use were old and sadly defective. Insulation of lines was still so imperfect that severe thunderstorms often caused much trouble in the transmission of messages. During Edison's first stay in Louisville, the cable across the Ohio River, establishing connection with the line to Cincinnati, had a fluctuating leak. This was bad enough, because of the extreme variations it would produce in the strength of the current; but when it was combined with high-jinks in the land wires, the general effect

[2] This follows the itinerary given by Dyer and Martin. The precise chronology is somewhat difficult.

was decidedly confusing. When Edison was for the second time in Louisville, the wires worked so badly that, as he afterward estimated, he had frequently to supply from conjecture or by absolute invention as much as one-fifth of the matter of the "press report"—that is, the news items received for the Associated Press.

"I never was caught but once," he related.[3] "Please notice that I said 'caught.' I made plenty of minor mistakes. But once I was caught. I had been working on the wire three months, I guess, and getting along very well. Then, as now, I had a good memory, and, in order to keep in touch with the news matter I was handling, I used to take an armful of exchanges home with me each night, pile them on my bed and read them, sometimes until two o'clock in the morning. In this way I kept pretty good track of what was going on in the country.

"Down in Virginia the Legislature was trying to elect a United States senator. John M. Botts [4] was the leading candidate. But he never received quite enough votes to elect him. Day after day, the sessions dragged along. One day news came that the opposition to Botts was going to pieces and that he would undoubtedly be elected the next day. The next day, just as a despatch from Richmond began to come, the wire 'broke.' The wire broke just as I had received the name 'John M. Botts.' I took a chance and wrote out a despatch to the effect that Botts had been elected. The Louisville papers printed it. The following day, they printed a correction. Botts hadn't been elected. The Legislature, as usual, had only adjourned for the day."

[3] A. L. Benson, "Wonderful New World Ahead of Us," in the "Cosmopolitan Magazine," February, 1911.

[4] John Minor Botts (1802–1869), representative in 1839–1843 and 1847–1849; author of "The Great Rebellion, Its Secret History" (1866).

Even now, telegraph offices may be described as for the most part scarcely luxurious in their appointments. In those days they were positively bleak. The office in which Edison worked during his first Louisville stay may be taken as fairly typical of common conditions, not only in the Middle West but throughout the country. The office, though on the main business street, was in the second story of a dilapidated building. The operators' room was dingy and likewise dirty. It boasted a little stove with a very long and very sinuous pipe. From fully a third of the ceiling, the plaster had dropped. The instruments were on a dozen diminutive tables set against the walls. To the small switchboard ran slim copper wires, ancient and unsound. As for the switchboard itself, its brasswork, never cleaned, displayed the accumulated effects of oxidization and of the metallic arcs that were formed when lightning hit the wires. In the yet more desolate battery-room, amid heaps of bundled messages and discarded record-books, was a stand supporting an old-fashioned battery of one hundred cells of the Grove type—cells, that is to say, in which the negative plate was immersed in concentrated nitric acid. The acid had gnawed at stand and floor, and gave out fumes by no means agreeable.

Of such a sort were the working quarters usually provided for the operators, whose domicile would quite regularly be a boarding-house with cheap rates and cheerless accommodations—an establishment of the variety once described by Edison when he referred to his hall bedroom as "a paradise for the entomologist" and the cuisine as "run on the Banting system of flesh reduction." In any larger office, some of the operators were likely to be happy-go-lucky; irresponsible to the point of recklessness, though sometimes possessed of a certain vagabondish phi-

losophy; and prone to take advantage of the fact that since, by reason of conditions, their services were at a premium, their vagaries would be generally tolerated. Though their wages were for those days relatively high, these operators were characteristically out of funds. Of this ilk was a chap who was working in the Cincinnati office when Edison was first there, and who suddenly left for Colorado. Several months after his departure, at about two o'clock one morning, while the night shift (including Edison) was busily working, a tin box descended with a resounding bang into the midst of the operators' room. It was followed by the visitor to Colorado, who remarked: "Gentlemen, I have just returned from a pleasure-trip to the land beyond the Mississippi. All my wealth is contained in my metallic travelling-case, and you are welcome to it." The "travelling-case" held a solitary paper collar.

One of the constitutional rovers among telegraphers was "Milt" (Milton F.) Adams, whom Edison first met at Cincinnati in 1865, and who, after forty years, was still one of the unwearied and picturesque "Ishmaelites of earth." He and Edison became friends, and for Edison he was long the subject of amusing anecdotes. Then there was Hank Bogardus, commonly styled "Bogie." In 1914, in conversation with Walter P. Phillips, another old-time telegrapher, Edison mused: "Good fellow, Hank. Fine operator, too. . . . He came out here [*i. e.*, West Orange] about two years ago and wanted five dollars, with which I supplied him. No one could turn the old boy down. . . . He went away and returned in three or four days. He looked like a tramp and his breath was like a whiff from a charnel house. This time he wanted ten dollars. No, I said, you get only five; that breath, Bogie, is going to cost you $5, and besides that you must

go away from Orange. He wanted $10, but I was inexorable and I said to him sternly, Henry Bogardus, I will not be party to the encouragement of intemperance. So he reluctantly accepted the five and was on his way."[5] Bogardus, gifted though he was, ended his days in a freight car by death from exposure. Such tramp operators, like their congeners, the tramp compositors of the printing trade, are figures of the vanished past.

Representative of the best class of telegraphers was George Kennan, who was born in 1845 in Norwalk, Ohio, only four miles from Milan, which he often visited; learned telegraphy; and took charge of the railway telegraph office in Norwalk. Kennan entered the Cincinnati office in August, 1863. He rose to be its assistant manager, and in December, 1864, left it in order to go to Siberia, where he superintended line construction for the Russo-American Telegraph company. He afterward explored the eastern Caucasus and for several years was night manager in Washington, D. C., for the Associated Press. In 1885–1886, under commission from the "Century Magazine," he was in northern Russia and Siberia, travelling 15,000 miles while investigating the Siberian exile system of the Czarist government. The results of his studies appeared in his famous work "Siberia and the Exile System," published serially in the "Century" and afterward in book form (2 vols., 1892). This has been called "the most comprehensive and fearless exposition ever made." In subsequent years Kennan's duties as staff-correspondent of "The Outlook" took him to Cuba during the Spanish-American War and to Manchuria during the Russo-

[5] See Phillips' article, "Edison, Bogardus and Carbolic Acid," in the "Electrical Review and Western Electrician," November 14, 1914. Phillips (1846–1920) was the inventor of Phillips' Morse automatic telegraph, and for several years was connected with the Columbia Graphophone company at Bridgeport, Connecticut.

Japanese War. Others of his books are "Campaigning in Cuba" (1899); that fascinating collection of stories and sketches "A Russian Comedy of Errors" (1915); and a two-volume biography of E. H. Harriman (1922). He died suddenly at Medina, New York, on May 10th, 1924. Some two years before Kennan's death, a prominent editor and publicist wrote thus to the author: "I regard Mr. Kennan as one of the finest types of American citizen that this country has produced. His clarity and absolute integrity of thought is really beautiful. . . . And he has had a much greater influence on American political life than general publicity gives him credit for. One of the best pieces of journalism in my time was his investigation and exposure of the corrupting influence of Addicks [6] in Delaware. These articles appeared in 'The Outlook' and literally drove Addicks from public life. I never knew anyone more painstaking in getting the facts or more courageous and unswerving in following the logical deductions from those facts." [7]

In one of his delightful letters to the author, Kennan once said: "Although we [Edison and himself] were nearly of the same age, lived as boys only four miles apart, and were both telegraph operators, we never happened to meet until we had passed the Biblical span of life. . . . Then I made his acquaintance, by telegraph, at a dinner of the Ohio Society, where he was an honored guest and

[6] J. Edward Addicks, promoter and capitalist, commonly known in his day as "Gas" Addicks because he controlled the gas supply of Wilmington, sought by hook, crook, and main strength to accomplish his election as a Republican United States senator from Delaware. For several years (ending in 1906) he was a disturbing and baneful factor in both state and national politics.

[7] See the editorial tribute in "The Outlook" of May 21, 1924, pp. 90–92; also the article by W. W. Ellsworth in the same publication, October 1, 1919, condensed from the same author's "A Golden Age of Authors" (Boston, 1919).

sat on the stage. Half a dozen old telegraphers, who had a table of their own near the center of the hall, had rigged up a telegraph line to the stage where Edison had a key and sounder. In an interval between the speeches, one of them came over to my table and asked me if I didn't want to speak to Edison. I replied, 'Certainly! I have never met him, but we were born only four miles apart more than seventy years ago, and it is time that I made his acquaintance.' So I went over to their table, called Edison by telegraph, and introduced myself. I had hardly touched a key before in fifty years, and Edison, I presume, was equally out of practice; but I talked with him more easily by wire than I afterward did by voice, because his deafness did not seem to extend to the ticking of a sounder." [8]

It is the privilege of the present writer to quote at length from autobiographical material prepared by George Kennan to be deposited among the records of the Firelands Historical Society of Norwalk, Ohio. These recollections of the Cincinnati office as it was in 1863–1864 are of peculiar value, having been written out by one markedly qualified both as an observer and as an author. They picture in a lively manner something of the picturesque side of a bygone phase in the history of American telegraphy; and so far as concerns this volume, they furnish a background that helps us more fully to un-

[8] On October 19, 1915, while in San Francisco, California, to attend the Panama-Pacific International Exposition, Edison was guest of honor at a telegraphers' banquet which he said was the first banquet he had ever attended at which he could not only talk but also hear all that was said by the speakers on the programme. The speechmaking was through telegraph sounders. Wires were stretched from one table to another and each table had a sounder connected to the general circuit. At Edison's place was a special resonator. In addition to listening, he ticked out a brief Morse message to his fellow-diners. ("Electrical World," October 30, 1915.)

derstand Edison's days as a telegrapher. For Kennan did not leave Cincinnati until December, 1864, and Edison arrived there in February, 1865, when the general features of office life must have been largely similar.

Says Kennan: "The Western Union Telegraph office at Cincinnati, when I went into it as an operator in August, 1863, was the most important distributing station in the Middle West. There were no quadruplex instruments in those days; long-distance circuits were not common; and all press-news, war-despatches, and commercial telegrams going westward from Washington, New York, Pennsylvania and New England, or eastward from Kentucky, Indiana, southern Illinois and Missouri, were written out in the Cincinnati office and re-sent to their destinations. We had, it is true, a couple of 'Hicks' repeaters,' by means of which we sometimes put Buffalo or Pittsburg in direct communication with Louisville and St. Louis; but, as a rule, all business was received in Cincinnati by one set of operators and forwarded from there by another.

"The whole expert force of the office was divided into two shifts, or watches, which worked days and nights in alternation. On Monday, for example, shift No 1 was on duty from 8 A. M. until 6, and shift No 2 from 6 P. M. until all the hooks had been cleared. On Tuesday, shift No 2 took the day trick, while shift No 1 worked until 2 o'clock in the morning. This alternation of hours was extremely trying, of course, to the health, for the reason that it broke up all regularity of life. One day we spent most of the forenoon in bed and worked three-fourths of the night; the next day we had to get up at 6.30 and were "off" before dark. Half the time our latest meal was a six-o'clock dinner, while in the other half we had a midnight lunch of doughnuts and greasy pie, which a night-

lunch peddler brought to the office, and which we ate as we worked. The business that we had to do was out of all proportion to the strength of the force, and after every battle in Virginia or the Southwest, the 'specials,' Associated Press despatches, and war-telegrams in cipher, were so numerous and so long that we had to work at them all night. The order of business was, private messages until 9 P. M., 'specials' and news until the papers went to press about 2, and then private messages again until morning. Many a night I went on duty at 6 P. M., and never left my chair until I was relieved by a man coming from breakfast at eight o'clock the next morning. Once, I had only ten hours sleep out of seventy-two.

"The result—or one result—of this press and rush of work was the formation of a body of telegraphers who, in point of skill, swiftness and endurance, have never been surpassed in any part of the world to which the great invention of Morse has spread. 'Dick' Duncan in Pittsburg; the Bunnells in Buffalo; Everett and L. C. Weir in Cincinnati, and many others who might be named, in the larger city offices of the East and West, were probably the most expert operators that the art of telegraphy has ever produced. It was a tradition in the Cincinnati office, when I reached there, that L. C. Weir, who afterward became the general superintendent of Adams Express Company,[9] once received two streams of press report, from two separate instruments, copied one with each hand on manifold sheets, and at the same time carried on a gen-

[9] "Mr. Weir was successively general superintendent, in charge of the territory west of Pittsburgh; later elected a member of the board of managers; then a trustee; then to the presidency, and on his retirement from that office was elected chairman of the board of managers and board of trustees. His services covered practically a half-century."—H. H. Gates, secretary of the Adams Express company, in a personal letter to the author.

eral conversation with the men who were watching him. This tradition, of course, must be taken with due allowance for fanciful invention and artistic embroidery; but Mr. Weir was really an operator of extraordinary skill, and was particularly distinguished for his ability to 'copy behind.' On one occasion, when General Stager [10] made a visit to Cincinnati, and happened one morning to be in the office Mr. Weir, with a boyish pride in his expertness as a receiver, thought he would 'show off' a little for the benefit of the superintendent. He was working, at that time, the eastern wire, and when Pittsburg called up, about nine o'clock, and said he had fifteen or twenty 'through' telegrams, Weir said indifferently, 'All right, go ahead!' Pittsburg began to send at the rate of about thirty words a minute. Weir made a show of searching all his pockets for a pencil, but failed, apparently, to find one. General Stager, who was himself a good operator, looked on with interest and expected, of course, that Weir would stop Pittsburg and say, 'Hold on a minute while I get a pencil'; but this was not part of Weir's plan. Rising lazily from his seat, he walked slowly across the big operating room, where twelve or fifteen other instruments were noisily banging away, went to the desk of Stevens, the chief operator, and asked for a pencil. Stevens got out his keys, unlocked his desk and gave him one. Weir went back to his table, looked at the pencil for a moment in a speculative way, and then began to feel in his pockets for a knife with which to sharpen it. Not finding one— or pretending not to find one—, he again crossed the room

[10] Anson Stager was general superintendent of the Western Union Telegraph company, and military superintendent of telegraph-lines throughout the United States during the Civil War. He was commissioned brevet brigadier-general for his services. Stager, whose home was in Cleveland, originated the Federal telegraphic cipher-code, later developed by himself and others.

and borrowed a knife from one of the local-circuit men. Returning to his table, he sharpened the pencil deliberately, put a fine point on the lead, and then, taking a pad of soft paper in his lap, he put his feet up on the table and began to copy;—making elaborate flourishes and curlicues, as if he had worlds of time to spare. Pittsburg, meanwhile, had been sending steadily at the rate of thirty words a minute, and was more than three messages ahead. Weir finally stopped flourishing; settled down to business; wrote telegram after telegram with ever increasing swiftness, and soon began to catch up. In five minutes he was only two messages behind; in ten minutes he was within one telegram of the sender; and in a quarter of an hour, he had recovered all the ground that he had intentionally lost, and was putting the words down on paper as fast as they came from the instrument. General Stager watched the performance in silence, and when Weir had finally caught up, he said dryly, 'That's all very fine, Mr. Weir; it's the most wonderful thing I have ever seen in the way of telegraphing; but I wouldn't do it again.' [11]

"The ability to 'copy behind,' that is, to remember a constantly changing body of words, while receiving at a high rate of speed, seems to be a natural gift—like the ability to play a dozen games of chess blindfolded. The almost incessant practice that I had in Cincinnati eventually made me a very expert receiver, or sound-reader; but if, in copying, I happened to fall behind the sender, even to the extent of a dozen words, I was lost. I could

[11] Weir did that sort of thing more than once; in fact he liked to "show off" in that way. I am sure that my details are right, because I *saw* the whole performance and I remember well General Stager's comment on it. The latter cautioned Weir against the practice because he was afraid that Weir would omit something and so lay the W. U. open to a suit for damages.—George Kennan, in a personal letter to the author.

not write down one word while my brain was taking in another, and, at the same time, remember the constantly changing volume of ten words that intervened. One night, about two o'clock, 'Dick' Duncan, who was sending to me from Pittsburg, said, 'I've got about a hundred "through" telegrams left. If you won't break, I'll send them to you in an hour.'

"'All right,' I replied, glancing at the clock, 'fire away! I'll do my best.'

"He began sending at the rate of about thirty-five words a minute, and gradually increased his speed, until, with the help of a few simple abbreviations, such as 'hw' for 'how,' 'hv' for 'have,' 'ts' for 'this,' &c., he was spelling out in dots and dashes more than forty words every sixty seconds. His manipulation of the key was almost perfect in time and spacing, but I had to strain every faculty of mind and body to keep up with him. Three or four times I fell a little behind, as the result of failing, at the first attempt, to tear a sheet off the clip. The ground that I thus lost I could not possibly recover, and I had to lay three or four telegrams aside to be filled in later. I knew what words should go in, but I could not get time to write them in, without breaking. There proved to be ninety telegrams in the lot, and I received them in fifty minutes, without a break. This, for some time, stood as the high-speed record of the office. . . .

"In the early part of 1864, when gold had risen to a high premium, and when its value, as measured in greenbacks, fluctuated widely from day to day, in sympathetic correlation with the favorable or unfavorable nature of the war news, we began to receive complaints from bankers and brokers on Third Street to the effect that the contents of private telegrams, sent to them by their correspondents in New York, leaked out of the Cincinnati

office, in some way, and became known to a certain stock-jobber and speculator on the street before the telegrams themselves had been delivered. This speculator never received any gold quotations of his own from New York, and yet his information seemed to be better and later than that of anybody else. As I had, by this time, taken a leading position in the office, Stevens, our chief, asked me if I had any reason to suspect the trustworthiness of any of our day men. I replied that I had not, and that it was practically impossible for our operators to communicate with the street during business hours, because they were not allowed to leave the operating room. He suggested that a man might send out notes, after seeing the stock and gold telegrams from New York, and might get such notes to the speculator while press copies of the telegrams themselves were being made in the delivery department down stairs. I said that I felt sure this could not be done, regularly and systematically, without attracting my attention; and that, furthermore, the only person who saw the gold and stock telegrams from New York was the man who worked the Pittsburg wire; and he could not stop receiving, every few minutes, to write a note, without eliciting a protest or a complaint from Pittsburg. I said, however, that I would keep my eyes open, and watch the gold and stock telegrams until they went down stairs in the 'dummy.'

"Three or four days later, I discovered—or thought I had discovered—the leak. The Western Union Company, at that time, maintained a branch office at the Burnet House, for the convenience of the latter's guests. This local office was connected with the main office by means of a loop, which ran to our switch-board and could be thrown into any one of twenty different circuits. When the Burnet House operator had a telegram for

Cleveland, or Louisville, or Indianapolis, he asked us to put his loop on the Cleveland, or Louisville or Indianapolis wire. I happened to notice, one forenoon, that he called for the Pittsburg wire about the time that the gold and stock telegrams began coming from New York, and the conviction suddenly flashed upon me that he was the thief, and that the leak was in the Burnet House. Stock-brokers, in those days, did not have special wires, and all their telegrams went through the delivery department of the general office, where there was more or less delay. By listening at the Pittsburg wire, and sending a swift messenger to the dishonest speculator, whose office was only a short distance away, the Burnet House operator could beat the very telegrams from which he had stolen his quotations, and give his confederate ten or fifteen minutes in which to buy or sell, before the state of the New York market became known on the street.

"When I gave Stevens my reasons for suspecting that the Burnet House operator was the man for whom we were looking, he said cheerfully, 'All right! We'll set a trap for him. If he's innocent, it won't hurt him; but if he's guilty, it'll break his back.'

"That afternoon, he prepared fifteen or twenty fictitious telegrams from well known New York firms to their correspondents in Cincinnati, purporting to give the latter notice of bad news from the theater of war in Virginia, a panicky feeling in Wall Street, and a great jump in the price of gold. At the same time, he notified the complaining brokers on Third Street that he thought he had found the leak; that he was going to let false information out through it on the following morning; and that if the speculator who always had the earliest news should manifest a desire to buy gold, it would be well, perhaps, to facilitate his operations and 'load him up.'

"When the Burnet House operator asked to be put on the Pittsburg wire, the next forenoon, as we had anticipated that he would, I switched his loop into a little-used local circuit known as the 'Camp Dennison wire,' where Stevens was already sending the fictitious telegrams with a very skilful imitation of the Pittsburg operator's key-writing and speed. The trap was set; and in less than ten minutes, it closed with a snap, 'breaking the back' of an untrustworthy telegraph operator and virtually ruining a dishonest stock-broker. The former was discharged with a blasted reputation; while the latter, who had 'plunged' on the false news, went to the wall, and shortly afterward left the street.

"In the early part of 1864, I was appointed assistant chief of the Cincinnati office, with a salary of $1600. This promotion gave me an authority that I had not previously exercised, and added to my responsibilities; but it did not shorten my hours of labor, nor relieve me from much of the drudgery of the instrument tables. I still had to do an operator's work in sending and receiving messages and press report; and was expected, in addition, to test wires, locate 'crosses' and 'grounds,' do most of the switching at the board, and take full charge of the office in Mr. Stevens' absence." . . .

"Cincinnati, at that time—toward the close of the Civil War—, was a much rougher and more lawless city," adds Kennan, "than it ever has been since. Fights, street robberies, and murders, were of daily occurrence, and all of the men in our office who had to do night duty carried weapons, as a matter of course." Conditions in time improved, but that traces remained of the post-war disorganization is evidenced by the fact that so late as 1884 a mass-meeting of citizens was held in protest against the prevailing slack enforcement of the law.

"Milt" Adams, who was then something of a fop, has described Edison, when he first appeared in the Cincinnati office, as "decidedly unprepossessing in dress and rather uncouth in manner." Edison himself has related that when he first went to Louisville he was "not much to look at"; and that although the weather was bitterly cold, he was wearing a linen duster. A portrait of him from a photograph made in 1866 shows, however, conventional garb and neatly-brushed hair. It also shows a face characterized by a sensitive mouth, a prominent nose, a high forehead, and eyes with an alert yet concentrated expression. Then, as afterward, Edison was smooth-shaven. In those years he was rather thin.

Of his skill at the key, he once remarked, "In fact, I was a very poor sender, and therefore made the taking of press report a specialty." But "Milt" Adams, a well-qualified judge, once said of his friend, "As an operator he had no superiors and very few equals." When Robert Underwood Johnson (poet; successively associate-editor and editor of the "Century Magazine"; and ambassador to Italy in 1920–1921) was eleven years of age—that was in 1864—he was assistant to the station agent of Centerville in Wayne county, Indiana; selling tickets, making out way-bills, keeping accounts, and learning "the not unromantic work at the telegraph key." [12] "I soon became expert in sending a despatch," he writes, "and can still do so, but in receiving I was always in the second class. The most interesting work was at night when I stayed to report the midnight train, meanwhile chatting now and then with acquaintances on the line. A memorable experience of this episode, which lasted hardly a year, was to listen for what might be called the autograph of a certain operator in the 'B' office at Indianapolis named

[12] "Remembered Yesterdays" (Boston, 1923), p. 59.

Edison! The telegraphic style of the great inventor that was to be was unique and was detected by its lightning-like rapidity. It was the despair even of expert telegraphers, who often had to break into his narrative to ask him to repeat."

Edison was all the while quietly working to become more expert. Even when in Indianapolis, he would seize every chance of relieving the regular press operator. In Cincinnati he was at first employed in the commercial department on a day wire to Portsmouth, Ohio; but at night he would still be found in the office, awaiting an opportunity to act as substitute for some operator who might wish to get away. One day a meeting was held to organize a local branch of the telegraphers' trade-union. Eight operators of the night shift were absent when the time came for them to go on duty. The few operators who happened to be in the office cared for the various circuits as well as they could. Edison selected the busy Cleveland press wire and received from it until he was relieved at three in the morning. His "copy" on this occasion proved to be so satisfactory that he was at once promoted from the ranks of the "plugs" or inferior operators to those of the first-rate men.

He was an excellent penman, and before his promotion he had added to his salary by making theatrical scripts. Later, when he was first working in Louisville, on a wire whose performances have already been described, he found it "very difficult to write down what was coming and imagine what wasn't coming." Therefore, to use his own words, "it was necessary to become a very rapid writer, so I started to find the fastest style." He evolved a vertical method by means of which he was able to copy as many as fifteen columns of press report during his "trick." This remarkably uniform and legible writing was nat-

urally pleasing to the newspaper compositors; and it was the primary means of bringing Edison to the East. He wrote to Adams, who then was in Boston, asking whether there was a job in sight. Adams was working for the Franklin Telegraph company; but as there was no vacancy in that office, he went to the Western Union superintendent and submitted Edison's letter as a specimen of the kind of "copy" the young Westerner could turn out. When the superintendent inquired whether Edison could take like that from the line, Adams declared he could, and that "there was nobody who could stick him"; and the superintendent thereupon said he was looking for just that sort of operator.

Like Kennan, Edison soon showed that he was neither a mere routine worker nor an idle waster of time. Always a great reader, he was fond of hunting for bargains in the second-hand book-shops. Once in a Louisville auction-room, he got twenty volumes of the "North American Review," unbound, for $2.00. He had them bound and sent to the Western Union office. Early one morning, when he had finished work, he shouldered ten volumes and started for his lodging. Before long, he became aware of bullets flying about his ears, and then was seized by an irate policeman who demanded why he had kept on when ordered to halt. Edison explained his deafness and the contents of his package; and the officer, who, of course, had fancied Edison to be a thief, confessed to poor shooting.

Of his studies when an operator, Edison said, "I practised for a long time to become a rapid reader of print, and got so expert I could sense the meaning of a whole line at once." This reminds one of what Trevelyan calls "Macaulay's extraordinary faculty of assimilating printed matter at first sight." "To the end," says Tre-

velyan, "he read books faster than other people skimmed them, and skimmed them as fast as anyone else could turn the leaves. 'He seemed to read through the skin,' said one who had often watched the operation. And this speed was not in his case obtained at the expense of accuracy." [13] Nor was it, if we may judge, in the case of Edison, who possessed this power in a less degree. Although the young operator did not read much fiction, so devoted was he to Hugo that among his office-mates he is said to have been known as "Victor Hugo Edison." He was rather fond of the drama; and when in Cincinnati would quite often go with Adams to the old National Theatre to attend the performances of John McCullough, Edwin Forrest, and other distinguished players of the day. When he was first in Louisville, he was sometimes present at discussions between Tyler, local superintendent of the Associated Press, whose office was at the back of the Western Union operators' room, and George D. Prentice, a Yankee editor who had migrated to Louisville and had won a considerable contemporary reputation as editor of the Louisville "Journal" and as a poet. After the "Journal" had been "put to bed," Prentice was wont to come around for an early-morning chat with Tyler. Good talk might be heard, and Edison asked permission to drop in to listen when he had finished taking press report.

He had set out to penetrate the mysteries of electricity, which then was even more mysterious than it is now. From the time when he learned train telegraphy from Mackenzie, he was trying to get so-called "practical" telegraph men to explain how the telegraph worked. The best explanation he succeeded in getting was that of an old Scotchman, a line-repairer for the Montreal Telegraph company, who said that if you had a vastly

[13] "The Life and Letters of Lord Macaulay" (New York, 1876), I, 61.

elongated dachshund, long enough to reach from Edinburgh to London, he would bark in London if you pulled his tail in Edinburgh. This had a certain plausibility about it; but Edison admitted that he never understood what went through the dog. Much of his leisure was spent, according to Adams, in "monkeying with the batteries and circuits, and devising things to make the work of telegraphy less irksome." He was constantly experimenting. An experiment ended his second sojourn in Louisville. One night, needing sulphuric acid, he had recourse to the supply in the battery-room. A carboy of the acid was overturned, and the fluid leaked into the manager's office below, where it made havoc of the carpet and the managerial desk. Next day, notice was given him that the Western Union company desired not experimentalists but operators, and that his services were no longer required. He went to Cincinnati but soon quit; and from Port Huron he wrote (as we have noted) to Adams in Boston, asking whether work was to be had there. Adams' reply urged him to start at once, and this he did, having succeeded in obtaining a pass over the Grand Trunk. Characteristic of the innumerable legends that have collected about Edison, is the grave statement of one writer that the young operator "made his way to Boston, tramping the whole distance from his house in Port Huron to Boston in four days and four nights" [14]—a pedestrian feat that (especially since the time was winter and the weather uncommonly severe) would easily have placed Edison among the great walkers of the world!

14 James Burnley, "Millionaires and Kings of Enterprise" (London, 1901), p. 169.

V

THE TELEGRAPHER TURNS INVENTOR

After an adventurous railway journey, during which he was snowed in by a Canadian blizzard, Edison reached Boston. There was a five-minute interview with Superintendent Milliken, who gave him a job and asked him when he would be ready to report for work. "Now," said Edison; and Milliken told him to be on hand at 5:30 that afternoon.

Milliken was wise enough to discern the sort of operator he was getting; but the night shift of the Boston office saw only an uncouth-looking young fellow, clad lightly for such freezing weather. They thereupon put their heads together to rag the new arrival from the "woolly West." A seat at a special table was finally given to him. He was to take press from New York for the "Boston Herald"; but he did not know that his fellow-operators had arranged to have the message sent by one of the speediest men at the New York end. Having begun slowly, the sender increased his pace until he had soon reached the limit of his ability—but Edison continued to receive with ease. Then the New York man tried slurring the words and running them together; but Edison's experience in Cincinnati and Louisville had made him fully equal to this kind of thing. At last, when the message was about completed, Edison opened the key and advised New York, "Young man, change off and send with your other foot." It is not recorded

that Edison's associates attempted anything further.

In Boston the Western Union office was on the ground floor; but it was in many ways scarcely an improvement over the quarters to which Edison had been used in the West. The premises had previously been occupied by a restaurant, and swarms of cockroaches had their lair between the skirting-board and the wall. At midnight an old Irish vendor, known as the "cake man," would come around with eatables, and the operators would buy a bit of luncheon. Then the cockroaches sallied forth. They became such a nuisance to Edison that on the wall beside his table he fastened two strips of tin-foil. He connected one strip with the positive pole of the battery that furnished current to the telegraph wires, and the other strip with the negative pole. A cockroach would climb up the wall; and when he came in contact with both strips at the same time, there was a flash and the cockroach, as Edison said, "went into gas." A reporter for an evening newspaper wrote a half-column story about this ingenious device, but the night-manager did not fancy such publicity and the electrocutions were discontinued by request. "Milt" Adams told how Edison had once rigged a similar contrivance in the cellar of the building in which the Western Union had its Cincinnati office. The place was infested with rats, and Edison so prepared two insulated plates connected with the main battery that a passing rat would readily complete the circuit. He called this arrangement his "rat paralyzer."

One day the principal of a select Boston school for young ladies asked that a demonstrator be sent from the Western Union office to explain the Morse system of telegraphy to the "children." Already known as the most intelligent of the operators, Edison was selected for this purpose; and being always glad of additional funds for

his perpetual experiments, he agreed to "do the stunt." Adams went along. He and Edison ran a telegraph line across the schoolroom. Edison took up his station on the platform, while Adams waited at the opposite side of the room. When the door was opened, in filed the "children" —about twenty young ladies, none younger than seventeen and all in elaborate toilettes. As to exactly what happened thereafter, Edison and Adams were not agreed. Each related that the other was so embarrassed he couldn't utter a word. Each claimed to have saved the day. Edison, according to his version, when he viewed Adams' dumb embarrassment, started in and "talked and explained better than I ever did before or since."

Edison lived in a hall bedroom, which he shared with Adams when Adams was laid off and financially reduced to "absolute zero centigrade." ("I generally had hall bedrooms," was Edison's later comment, "because they were cheap." . . .) His meals he took at a boarding-house about a mile distant. He was constantly studying and experimenting. This, with his work as an operator, kept him busy from eighteen to twenty hours a day. Once he bought a complete set of the works of Faraday. He triumphantly appeared with the volumes at his lodgings at four o'clock in the morning, and read until breakfast-time. Then he said to Adams, "I have got so much to do and life is so short, I am going to hustle." With that, he started for the boarding-house on a run.

In those books of Faraday's Edison found a great stimulus. He liked them because of their clear explanations, free from complicated mathematical formulæ, and he tried almost all of the experiments. He browsed in the second-hand book-shops along Cornhill; and would spend his last cent for books, apparatus, and supplies, though he cared little about clothes. A new suit in which

on one occasion he invested thirty dollars, was promptly ruined with acid. "That," observed Edison, "is what I get for putting so much money in a new suit."

He tried not only the Faraday experiments, but many others that he ran across. In a scientific journal he found directions for making nitro-glycerin, and he was attracted by the possibilities of the preparation. He and an acquaintance manufactured some, but tests that they conducted with a small quantity were so disconcerting that early one morning Edison put the remainder in an empty pop bottle and lowered it into the sewer. Not always, however, did he escape accident. He had a borrowed induction-coil that he kept for experimenting in the shop of a man named Hamblet, who was then working on electrical clocks and who afterward, it is said, developed the Western Union system of distributing standard time. One day the young experimenter inadvertently took hold of both electrodes of the coil, and then he discovered that he couldn't let go. The Grove battery was on a shelf; and so far as he could see, the only way to get free was to back away with the coil, so that the wires to the battery would dislodge the battery-cells. This would, of course, break the circuit; but the nitric acid, in which the negative plates of the cells were immersed, might splash. Edison closed his eyes and backed away. The acid was spattered over his face and ran down his back. He rushed to a near-by sink and dashed water over himself as well as he could; but his face was temporarily so disfigured that for two weeks he did not go out by daylight.

Walter P. Phillips, a fellow-operator in the Boston office, in after years wrote of Edison as spending his salary on helices and coils; eloquent in explaining his diagrams of quadruplex telegraphy; but no longer

strongly attached to his once favorite work of receiving press report. According to Phillips, he wrote out 1,500 or 2,000 words of "press" in a hand so fine and a space so limited that the matter had to be copied for use by the newspaper compositors. Rebuked for this, he next made "copy" by writing but one word on a sheet, and that in the very center. After that, he was relieved of the press wire.[1]

On Court street one Charles Williams, a maker of electrical apparatus, had a workshop. There Edison was welcomed; and there, with the aid of one of Williams' workmen, he built a working model of his first patented invention. This was a vote-recorder, for which patent 90,646 was issued on June 1st, 1869. A telegraph operator named Roberts furnished capital to the extent of $100, and Edison's attorney was Carroll D. Wright, later director of the eleventh census and for twenty years United States commissioner of labor. The machine was designed to facilitate the taking of votes in legislative bodies. When a member closed a switch at his desk, the machine would record and count the vote. Edison thought it ought to be adopted by the Federal House of Representatives, and so he made the trip to Washington to demonstrate it before a committee. It worked to perfection, but the chairman of the committee informed the inventor that no invention could be less desirable for the House of Representatives than a vote-recorder. He made it plain that one of the means by which a minority might block ill-considered legislation was "filibustering" —a method of gaining delay and tiring the majority by long speeches, technical objections, and futile motions. And with filibustering, a vote-recorder would obviously interfere. Edison resolved to devote his abilities thence-

[1] "Sketches Old and New" (New York, 1897).

forth to inventions for which there was likely to be a demand.

In accordance with this resolve, he invented a stock-ticker and introduced a ticker-service for which he had about forty subscribers. The appearance in 1867 of the first ticker—the invention of E. A. Callahan—had set many an operator to experimenting in the same direction. Edison journeyed to New York in an unsuccessful attempt to dispose of his ticker. He also devised an instrument with an alphabet-dial, for direct telegraphy between business houses. Under his direction, private lines were strung along the roofs. The instruments were so simple that the average person could in a few minutes learn to operate one. He had them made in Hamblet's shop. Gradually he was finding his true vocation.

After a time, "Milt" Adams went westward on his cycle of roving. Edison, for his part, decided to have done with telegraph operating and to devote himself to invention. Considerably in debt, but bound to improve his fortunes and to seek broader fields, he left the employ of the Western Union and quit the Hub.

VI

UNDER WAY

When Edison started for New York, he had only money enough to pay for the boat trip. His instruments and books were perforce left in Boston. He not only was insolvent, but even lacked the cash to buy his breakfast when he went ashore. As he walked along one of the down-town streets, he passed a warehouse where he saw a tea-taster inspecting teas. He asked the taster for some of the tea, which the man kindly gave him. Such was his first meal.

He had an operator acquaintance in New York; but it chanced that this operator, when at last found after a considerable search, was likewise out of a job and had but a dollar to spare. To the tired, hungry Edison, however, a dollar was a hundred cents better than nothing. He proceeded to order apple-dumplings and coffee in Smith and McNell's restaurant, just across the way from Washington Market and long known, even beyond the limits of New York, for its good food. He once said that in all his life he never ate anything that looked more inviting. That same day he applied for work with the Western Union; but there was no vacancy, and he was put on the waiting-list. Somehow he got permission to pass the night in the battery-room of the Gold Indicator company, and thus the problem of lodging was temporarily solved.

The Gold Indicator company, and the "gold-reporting

telegraph" that it controlled, owed their existence to certain special conditions of the time. Towards the close of 1861, the banks had suspended specie payments, and the Federal government had begun to issue large amounts of paper-money. Throughout the United States, with the single exception of California, gold ceased to be a medium of exchange. The national banks redeemed their notes in government paper. As the government fell more deeply in debt, its promises to pay came to be considered much less valuable than gold, and gold consequently went to a premium. In 1863 the price of gold in paper-money reached 170; in 1864 it touched the quotation of 285, though according to some authorities the actual price probably never went much above 250. This disparity in value between gold and government notes continued until the Federal treasury resumed specie payments on January 1st, 1879.

Under these circumstances, gold naturally became the chief object of speculation. In Wall street a Gold Exchange was introduced, under the direction of its own board and exclusively devoted to transactions in the standard metal. The "gold room" was the converging-point of the activities of "the street." At first the quotations were chalked up on a blackboard, as they are to-day in brokers' rooms. A small army of crowding, noisy messenger-boys carried the changing information to private offices. After a time, the vice-president of the exchange, Dr. S. S. Laws, invented an electrical indicator to exhibit the quotations, and this was operated with keys by the registrar of the board. It did not do away with the scuffling, noise, error, and loss of time involved in the system of messenger-boy distribution.

Finally Laws hit on the scheme of a central transmitting instrument, with indicators controlled therefrom

in the offices of subscribing brokers. This gold-reporting telegraph Laws patented. Having resigned from the exchange, he formed the Gold Indicator company, to which distribution privileges were granted. In a comparatively short time he had three hundred subscribers to his service. The transmitting instrument, a complicated and by no means quiet affair, was located in the company's office and controlled by a keyboard on the floor of the gold room. The indicators were box-like constructions, with a horizontal row of dials travelling past a slot through which (as in fare-registers on street-cars at the present day) the figures were shown.

On the third day after his arrival in New York, Edison was sitting in the company's office. He had not yet found employment; and apparently the battery-room was still his shelter by night. During the daytime he had been studying Doctor Laws' telegraph system. All of a sudden, on this third day, the transmitter came to a standstill. There were two or three minutes of surprised silence—then up the stairway rushed some three hundred boys, all shouting at once that the indicators were out of order. The superintendent lost his head, and had not the slightest idea as to what was the matter. At this juncture Edison stepped to the instrument, which, as it proved, he had been examining to good purpose—so good, in fact, that he now surmised where the difficulty might be, and quickly detected it. A contact-spring had broken and dropped between the two gear-wheels. Then in came Doctor Laws, in no very calm frame of mind. The superintendent was dumb; but on Edison's saying that he believed *he* knew what the trouble was, Laws burst out, "Fix it! Fix it! Be quick!" Edison, who thought Laws the most excited person he had ever seen, thereupon removed the broken contact-spring and set the machine

at zero. A force of men was sent out to adjust the indicators; and in about two hours, service was renewed.

The upshot was that Laws, after a couple of interviews, offered to make Edison manager of the entire plant; and that Edison, having accepted, improved the Laws system in numerous ways and held the position until the Gold Indicator company was consolidated with the Gold and Stock Telegraph company. This company supplied a stock-quotation service that employed a type of indicator different from that of Doctor Laws. In this indicator, the invention of E. A. Callahan, two type-wheels printed a double line of characters upon a strip of paper tape. The quotations were sent from the Stock Exchange by the regular Morse system to a central station at 18 New street, whence they were transmitted to various brokers. After the consolidation of the two companies, the Laws indicator was retired and Callahan's new ticker took its place.

The most spectacular event of this period of speculation in gold, was the panic of September 24th, 1869—ever afterward known as "Black Friday." Jay Gould and his partner "Jim" Fisk had already won an unenviable notoriety through their purchase of judges, corruption of legislatures, and alliance with the Tweed Ring. In August, 1869, they embarked upon a cynical attempt to corner the gold market. They seem to have believed that they had influence with Grant's administration; and as they kept buying gold they drove the price rapidly upward. It is said they reasoned that as the price of gold rose, the price of western wheat would also rise to such a figure that the farmers would hasten to sell; whereupon enormous wheat shipments to the East would greatly increase the freight business of the Erie railroad, which they controlled. Whatever their motive, probably no

more thoroughly heartless example of financial buccaneering has ever been known in this country. At the eleventh hour their attempt was defeated by George S. Boutwell, secretary of the treasury, who ordered the sale of gold by the government. The market broke with the "Black Friday" panic, when in one trading day the price of gold dropped from 162 to 135. Much of this panic Edison saw; and part of it he was.

Quotations were at first forced upward so rapidly, that September day, that Doctor Laws' gold indicators simply couldn't keep step with them. It was one o'clock in the afternoon before Edison, by vigorous efforts, managed to get the machines abreast of the correct gold-room figures. This was his chief concern; and when the right quotation had been reached, he calmly watched the frenzied throngs that surged about the exchanges and blocked the streets. A Western Union operator congratulated him with, "Shake, Edison, we are O. K. We haven't got a cent." Late into the night the crowds continued aimlessly to walk the streets; late into the night the lights burned in brokers' offices, where clerks toiled amid a snarl of records and accounts; and late into the night Edison was striving to get the refractory indicators down to the low figure.

There was something almost amusingly characteristic in the phlegmatic detachment of this young man of twenty-two. He had already invented a stock-ticker; he was now the manager of the Gold Indicator company; and he was afterward interested, as both inventor and manufacturer, in stock-tickers. Yet he never speculated; and to him the scenes of Black Friday were but so many curious phenomena. A dozen years later, when the first central station of his incandescent electric lighting system was being installed in New York and a method of distribution worked out, while shares of the Edison Electric

Light company were advancing in price from $100 to $3,500 (and gas stocks rapidly falling), he appeared to his associates equally calm. He was occupied with what he considered his real business—the job of getting the station properly started.

A week after Black Friday—on October 1st, 1869—was published in the "Telegrapher" what is believed to be the first advertisement of electrical engineering service ever printed in this country. It announced the partnership of Edison and Franklin L. Pope, a young telegraph engineer who also had been connected with the Gold Indicator company, and who subsequently was editor of the "Electrical Engineer" and a recognized expert. The style of the new firm was "Pope, Edison & Co.," but J. N. Ashley, publisher of the "Telegrapher," also became a partner. The office was at 78 Broadway, but during most of his working hours Edison might have been found conducting experiments in a little shop in Jersey City. He boarded with Pope at Elizabeth, which he usually reached on a train leaving Jersey City at one in the morning.

Pope and Edison invented a "gold printer," for recording gold quotations and sterling exchange, and designed for use principally by exchange brokers and by importers. They also undertook to build and equip private telegraph lines. Their business was absorbed by the Gold and Stock Telegraph company; and before long that company was acquired by the Western Union. Marshall Lefferts, its new president, asked Edison to see what he could do for the improvement of the stock-ticker, which was still crude in many respects. Money for Edison's experiments was supplied by Lefferts, and Edison developed a series of inventions on which he obtained patents. One, for example, was a device called the "unison stop," where-

by all the indicators might be brought to zero directly from the central office, and thus made to record in unison with the transmitting instrument and with one another. If an indicator happened to "go wild," it might thus be set right without the delay and trouble involved in sending repair-men to the subscriber's office. The final result of these experiments of Edison's was the Edison Universal printer, which came into very extensive use.

One day Edison was summoned to Lefferts' office, and Lefferts told him that he wished to settle the matter of the inventions. "How much," he said, "do you think you should receive?" Edison, though feeling that $5,000 would be about right, had decided to accept $3,000; but now even this seemed to him so large a sum that he replied by asking Lefferts to make an offer. "How would $40,000 strike you?" demanded Lefferts—and Edison came (to use his own words) "as near fainting as I ever got." He was able to speak to the effect that he thought the offer a fair one; and in three days he called by appointment to sign a contract and get his money. This was in the form of a check that is stated to have been the first he had ever received. For a first check, it was doing decidedly well.

Edison went to the bank on which it was drawn, and passed it in at a paying teller's window. The teller passed it back and said something that Edison in his deafness failed to catch. With the notion that he must somehow have received a worthless piece of paper, Edison sought Lefferts, who explained that the check must be endorsed and sent a clerk with him to identify him. The paying teller, who seemed to think the matter highly amusing and who must have considered himself a very funny fellow indeed, thereupon paid the entire amount in bills of small denominations. Edison laboriously stowed

them in every pocket; and then, fearing that they might be stolen, sat up all night. In the morning, bulging, he again appealed to Lefferts, who helped him to deposit the money and open his first bank account.

He had arrived in New York without work and without the means to buy a meal. Within a space of time that seems almost unbelievably brief, he had demonstrated his ability as an inventor, won a place for himself in the world of affairs, and gained financial independence. The story resembles one of the narratives of Horatio Alger.

VII

EDISON AND THE TELEGRAPH

EDISON at once began to evolve new plans. To use his own expression, his was "too sanguine a temperament to keep money in solitary confinement." He opened a large shop in Newark, N. J., and there started making stock-tickers and their parts for Marshall Lefferts. His day force of fifty men had shortly to be supplemented by a night shift; but night or day, Edison was foreman. Three or four times during the twenty-four hours, he would take a half-hour's sleep upon a work-bench and wake refreshed. During all his active career, it might have been said of him, as it was of Buffon, "Work was his necessity." In 1909 he stated that up to 1902 (when he was fifty-five), his average working day had been nineteen and one-half hours; since then, he thought, it would not exceed eighteen.

During 1870–1871 he opened two more shops. He was now a busy manufacturer; and a manufacturer he afterward, except for a brief interval, continued to be. Men who have been associated with him have testified that, try as he might to escape manufacturing, he kept finding that what others made for him did not satisfy his standards. In those early Newark days almost all the employees worked by the piece. Edison admits that he gave them "a good training as to working hours and hustling." Some of them were, when they came to him, wholly inexperienced and untrained. At one time, in connection with

certain experiments, a tub had been filled with soapy water, into which hydrogen had been introduced for the purpose of forming large bubbles. "One of the boys, who was washing bottles in the place," said Edison, "had read in some book that hydrogen was explosive, so he proceeded to blow the tub up. There was about four inches of soap in the bottom of the tub, fourteen inches high; and he filled it with soap-bubbles up to the brim. Then he took a bamboo fish-pole, put a piece of paper at the end, and touched it off. It blew every window out of the place."

On another occasion one of the men attempted to boil a quart of ether over an exposed flame. The ether promptly blazed up, and the Newark fire department had to be summoned. A hose was put through a window, containers holding chemicals were smashed, and the fumes overcame some of the firemen.

From the Newark period onward, Edison's enterprises provided for many men a kind of experimental school, especially in electrical engineering. In after years an organization was formed called the Edison Pioneers, made up of those who had been in Edison's employ prior to 1885. It was in the early Newark days that Edison obtained the services of John Kruesi ("Honest John," he was sometimes called), a Swiss mechanician, thorough, accurate, and expeditious. This trusted "handy man" afterward became superintendent of the Edison laboratory, and then engineer of the Edison General Electric works at Schenectady, N. Y. Another who at that time entered Edison's service, to remain in it for many years, was John F. Ott. Of Edison at their first interview, Ott said, "He was an ordinary-looking young fellow, dirty as any of the other workmen, unkempt, and not much

better dressed than a tramp, but I immediately felt that there was a great deal in him."

Long hours were the rule in Newark. Once, no fewer than forty-five of Edison's inventions were being developed in the shops. When report was made that all seemed to be going pretty smoothly, a favorite expression of the inventor's was, "Well, boys, now let's find the bugs." It is said that, special difficulties having arisen in connection with a large order of tickers, Edison locked the men in for sixty hours, until all the "bugs" had been removed and he was satisfied that every detail was right.

Edison had not been in Newark long, when the Automatic Telegraph company of New York turned to him for assistance. This company had a circuit between New York and Washington, and the system it used had been devised by an Englishman named Little. The message was prepared by perforating a narrow paper ribbon with groups of holes corresponding to the Morse dot-and-dash characters. Then this prepared ribbon was run through a transmitting instrument. Wherever there was a perforation, an electrical contact would be made with the cylinder over which the ribbon ran; and thereupon a current from the battery would pass along the line to the receiver at the other end. There the current acted upon another travelling paper ribbon, chemically treated in such a way that electro-chemical action would leave a record upon it.

Edison's improvements covered every phase of the automatic system, and made that system a commercial possibility. The perforators by which the message was prepared, the transmitting and receiving instruments, the chemical treatment of the receiving-ribbon—all these in turn he greatly bettered. He did away with the troublesome sluggishness of the wire on long circuits. In short,

he made it possible to transmit and record 1,000 words a minute between New York and Washington; 3,500 words a minute between New York and Philadelphia. Nor did he stop there, but later perfected a receiving-instrument by which the message was recorded not in the dot-and-dash characters of the Morse code, but in Roman letters. Such a record did not require to be translated from Morse before it could be sent to the addressee. With this added improvement, 3,000 words a minute were transmitted between New York and Philadelphia, and recorded.

Edison went to England for the Automatic Telegraph company, which had arranged with the British postal telegraph officials for a trial of the automatic system as developed by Edison. This trial had at that time no result. It would, however, appear to have been completely successful. The automatic system was ultimately adopted in Great Britain, and continued to be used there. Edison asserted that his improvements were appropriated wholesale, with neither credit nor compensation.

So far as the United States is concerned, sufficient contemporary evidence exists to show that in the United States the automatic system not only was proved to be wholly practicable, but for at least two years was actually employed with a high degree of success. Yet, in spite of this, it was abandoned. Further along in this narrative, certain suggestions will appear that help to account for this strange situation.

The next problem to which Edison turned his attention, was that of duplex and quadruplex telegraphy. As a matter of fact, even before he left Boston, he had worked on a duplex system. Duplex telegraphy means the sending of two messages over the same wire at the same time,

but in opposite directions. Several investigators had been studying this matter of simultaneous transmission before Edison took it up; and one American, J. B. Stearns, had attained promising results.[1] Among the many applications for patents in the field of multiple telegraphy that Edison filed in 1873, was one covering an invention by which not only was duplex telegraphy possible, but two messages could be sent over the same wire at the same time *in the same direction*. This new system was called the *diplex*.

In this invention, duplexing was obtained by variation in the strength of the current. At each end of the line was a differential (or neutral) relay—that is, an electro-magnet wound with two wires led from a battery; one wire being wound from right to left, the other (with an equal number of turns and of equal resistance) from left to right. When the key at the distant station is open and current passes through the two windings of the electro-magnet, two equal opposing actions are set up, each of which neutralizes the other. The current divides, half going to earth, half to the distant station. The relay does not, therefore, respond to signals sent from the home station; but at the distant station the receiving instrument becomes active when the operator there closes

[1] Stearns remedied a defect that seriously interfered with duplex telegraphy in its earlier forms. A telegraph-wire naturally has what is called electrostatic conductive capacity—that is, it acts as a condenser and tends to retain, as an electrostatic charge, a portion of each electric impulse that passes over it. Hence, appreciable periods of time were required for the wire to be charged by the current and then to become discharged. This condition limited the speed at which Morse signals could be sent and was a decided hindrance to effective duplexing. By introducing condensers into the line, Stearns balanced the electrostatic charge of the wire and thus helped to make duplex telegraphy a practical success.

the key. Such a relay being used at each end of the line, each operator controls the receiving instrument of the other; and thus duplex transmission is made possible.[2]

Diplexing was obtained by variation in the direction of flow of the current. Edison introduced at each end of the line a second relay, known as a *polarized relay.* This relay was composed of an electro-magnet with a single winding; and between the terminals of the electro-magnet, a swinging *permanent* magnet. If the direction of flow of current were reversed in the winding of the electro-magnet, the polarity of the magnet would likewise be reversed—that is, the north pole became the south. The polarity of the permanent magnet was, however, fixed—the end between the terminals of the electro-magnet was constantly a north pole. Hence, it would be attracted by the south pole of the electro-magnet, and would swing to that pole. If then the direction of flow of the current in the winding of the electro-magnet were reversed, the poles of the electro-magnet would be changed, and the permanent magnet would swing to the opposite side. The direction of flow of the current was reversed by reversing the battery; and this was effected by an instrument called a pole-changer. When the differential (or neutral) relay and the polar relay were combined, two operators could, with the same current, send two messages over the same wire at the same time and in the same direction. One operator varied the strength of the current; the other simultaneously varied the direction of its flow. Here were the elements of quadruplex telegraphy, by

[2] In his "Flame, Electricity and the Camera" (New York, 1900), George Iles quotes (pp. 212–213) from T. C. Mendenhall's "A Century of Electricity" (Boston, 1887) a passage—too long to be given here—in which a detailed analogy is drawn between this action and an imaginary process in hydraulics.

which at each end of the line were arranged two pairs of instruments; one pair responding to variation in the strength of current transmitted from the distant station, the other pair responding to variation in the flow of current; and neither pair being influenced by currents from the home station.

Other inventions of Edison's came to attract a greater amount of public notice, and to claim a fuller consideration by technical writers. It may, however, be doubted whether in all his career Edison solved with more originality and ingenuity a specific problem in applied electrical science. He himself commented that it was a puzzle "of the most difficult and complicated kind," whose solution demanded all his energies. Said he: "It required a peculiar effort of the mind, such as the imagining of eight different things moving simultaneously on a mental plane." . . . The practical hindrances to be overcome in adapting it to successful commercial use, may well seem to the layman little short of insurmountable.

In the winter of 1872–1873, Walter P. Phillips was, so he states, one of eight operators selected for special experiments with the quadruplex, under Edison's direction, in the New York office of the Western Union. Phillips says:[3] "It [the quadruplex] was then in a very crude state, and the signals came over it in a way to suggest to an imaginative person the famous rocky road to Dublin. Edison was always present, changing something here or there, and gradually a result, somewhat imperfect but constantly improving, rewarded his efforts. Finally he made us a little speech, saying: 'Boys, she is a go. The principle is all right, and the sharps upstairs can get the bugs out of it. We can not do it down here, for the troubles with telegraphic appliances can only be

[3] "Sketches Old and New."

gotten out in the same way the Irish pilot found the rocks in the harbor—with the bottom of his ship.' "

A story is told to illustrate Edison's absorption in the quadruplex. It is to the effect that he received an official reminder of back taxes unpaid, with the statement that if they were not paid at once, a surcharge of twelve and one-half per cent. would be added. He went to the City Hall and got in line for the proper window; but when his turn came, he could not remember his own name! Long afterward, he told F. R. Upton, an associate, that he did not regard the problem, while he was working at it, as involving miles of wire stretching across country, but considered that he was working merely from one room to another room adjoining. Up to 1910, it was estimated that by the quadruplex possibly as much as $20,000,000 had been saved in America alone in the single item of line construction; for one wire thus could do the work of four.

We next turn from the work-room to the board-room; from invention to "high finance." Edison, wishing to sell the quadruplex, tried in vain to arrange with the Western Union company for a trial. At last such a trial was obtained by an agreement on Edison's part with the chief electrician of the company that the said electrician should be known as joint inventor.[4] "At that time,"

[4] In its sketch of George Bartlett Prescott (1830–1894), who became superintendent of lines of the Western Union, the "National Cyclopædia of American Biography" says (V, 279): "He patented several inventions in connection with the telegraph, and also invented and patented an improvement in the quadruplex telegraph. He was a joint owner with Thomas A. Edison in all the quadruplex patents in this country and Europe, and they received a royalty from the British government for the use of the same in the United Kingdom. He introduced in 1870 the duplex telegraph, in 1874 the quadruplex telegraph (the most valuable addition ever made to the art of telegraphy), and in 1876 the use of pneumatic tubes in the transmission of messages."

explained Edison, "I was very short of money, and needed it more than glory. This electrician appeared to want glory more than money, so it was an easy trade." A successful test between New York and Albany took place in the presence of President Orton and of W. H. Vanderbilt and the other directors of the company.

The quadruplex was introduced on the lines of the company. Orton paid Edison $5,000 on account and then vanished "on an extended tour." Thomas T. Eckert,[5] the Western Union's general superintendent, assured Edison that not another cent would ever be forthcoming. He said, however, that he thought he knew a man who would buy Edison's interest in the invention. This man turned out to be Jay Gould; and it was likewise disclosed that Eckert was planning to leave the Western Union and assume charge of Gould's rival company, the Atlantic and Pacific. Gould was seeking control of the Western Union and rightly viewed the purchase of Edison's interest in the quadruplex as a significant step in the process. He paid $30,000 for Edison's share, and Edison was made chief electrician of the Atlantic and Pacific.

Then Gould bought the Automatic Telegraph company, under a contract to pay $4,000,000 in stock for the patents and wires of the company. After he had finally gained control of the Western Union, he repudiated this contract. Eckert, who became president of the Atlantic and Pacific, not only was personally hostile to Edison but also was foolishly opposed to automatic telegraphy, which accordingly was withdrawn. Edison in later years described Gould as a dry, unsmiling man with an atrophied conscience, who had no pride in constructive enterprise

[5] During the Civil War, Eckert had been chief of the War Department telegraph staff in Washington, with rank of major.

or public service but sought money for its own sake. "When Gould got the Western Union," he said, "I knew no further progress in telegraphy was possible, and I went into other lines." [6]

[6] ". . . He was an undersized chap, and quiet as a mouse. I never liked his face. It was dark, and covered all over with whiskers so you could hardly see him. . . . And he wasn't a healthy man, either. He was as lean as a parson's barn. Never seemed to me that he ate enough."—Bouck White: "The Book of Daniel Drew" (New York, 1910), pp. 216–217.——D. and M., I, 163–164.

VIII

EDISON AND THE TELEPHONE

WHILE in Newark, Edison was from time to time busied with problems other than those of multiplex telegraphy. For example, he contrived a new system of call-boxes for district-messenger service and organized a company of his own to introduce it. Both system and company were successful; but before long the company was sold to the Atlantic and Pacific Telegraph company.

During this period, Edison also invented an apparatus for preparing a stencil by means of which copies of hand-written matter might be produced. The writing was done with a stylus upon a special paper coated with paraffin and resting on a finely-grooved steel plate. The stylus pierced the paraffin and traced very minute perforations in the paper, which then could be used as a stencil. This apparatus was called the *mimeograph*. Edison afterward sold his rights in it to A. B. Dick, by whom it was manufactured in Chicago. When typewriting machines came into use, the mimeograph was adapted to the making of stencils with them.

In the development of the typewriting machine, too, Edison had a part. The particular form with which he had to do, was that on which a patent had been obtained in 1868 by Carlos Glidden and Christopher L. Sholes. Sholes finally came from Milwaukee to get Edison's assistance in rendering the machine commercially available; and Edison helped Sholes to make improvements in it.

In 1873 the Remingtons, the gunsmiths of Ilion, New York, bought it and began to manufacture it under the name "Remington." When Edison worked on it, it employed the now familiar type-bar principle, but each bar carried only one character and the alphabet was entirely in capitals (or upper-case letters). Prior to this time, various crude and rickety machines had been built both here and abroad; but the Sholes invention, as developed by Edison and others, was the first practicable device of the sort. Edison's connection with this popular accessory of modern life is not generally known.[1]

In Newark, Edison had the first place of his own to experiment and work in that he had known since he left behind the cellar at Port Huron, with its two hundred bottles. At one time he had four smaller shops in addition to the principal one. It was also while he was in Newark that he married Miss Mary G. Stilwell. Yet he seems never to have been quite at home there; and in the spring of 1876 he gladly forsook Newark for Menlo Park.

Luther Stieringer, a gas engineer who became associated with Edison in Edison's researches in incandescent electric lighting, says:[2] ". . . Mr. Edison found that the combined work of manufacturing and inventing taxed even his superhuman strength; in fact, the two occupations proved irreconcilable. If a new idea struck him, it had at once to be tested in a thousand different ways, with the help of every man within call; but this would hardly

[1] On September 12, 1923, the fiftieth anniversary of the "Remington" was celebrated at Ilion under the auspices of the Herkimer County Historical Society. At that time a memorial to Christopher L. Sholes (1819–1890) was unveiled. An interesting sketch of Sholes may be found in George Iles' "Leading American Inventors" (New York, 1912; in the Biographies of Leading Americans series, edited by W. P. Trent), pp. 315–337.

[2] "The Life and Inventions of Thomas A. Edison" (Milwaukee and New York, 1890).

do in a factory run upon a regular time schedule and expected to yield an immediate return for every dollar. In 1876, therefore, Mr. Edison relinquished manufacturing and withdrew to the world-famous Menlo Park, New Jersey, twenty-four miles from New York City." [Timetables of the Pennsylvania railway system give the distance as 25.2 miles from the station in New York.]

Menlo Park, in spite of its rather fancy name, was just a little knot of houses near a diminutive railway station. All about it stretched open country. One may still find it on the map in Middlesex county, New Jersey; it being on the Pennsylvania railroad, between Elizabeth and Metuchen. At Menlo, Edison discovered the retirement and quiet that he wished; there he finally possessed a real laboratory; and there he remained until 1887.

Before he left Newark, he had undertaken certain researches in telephony; and these were continued at Menlo upon his arrival. They began, apparently, with his studies in harmonic telegraphy, which had been successfully attempted by Elisha Gray as early as 1874. In the harmonic system (not at present in use), a vibrating reed or a tuning fork was employed to transmit over the telegraph line a series of electric impulses corresponding to its own rate of vibration—more commonly called *pitch*. At the receiving station, another reed or fork, similarly tuned, would give forth the same tone. By means of a telegraph key, this continuous tone might be broken up into the Morse signals; and thus a telegraphic message could be sent and received. Not only so, but other pairs of reeds or forks, each pair having its own tone (or note), could be used to send impulses over the same wire at the same time without interference of any one with any other. Each receiving reed or fork "selected" its own tone and "rejected" every other. By using a set of reeds arranged

in keyboard fashion before a set of electro-magnets (for which the reeds acted as armatures), Elisha Gray not only was able to send music but actually transmitted nine separate messages over the same wire at the same instant.

It would appear that Edison had been investigating the general principles of this system; and in 1875 he devised an apparatus intended to serve in analyzing the various waves produced by different sounds. A caveat filed in the United States Patent Office on January 14th, 1876, described this apparatus. One month later, on February 14th, 1876, Elisha Gray filed a caveat for the invention of a telephone; and on that same day, Alexander G. Bell filed an application for his first telephone patent. Gray's caveat was filed about two hours after Bell's application. A caveat, in this special sense, was a description of an invention not yet perfected; and the filing of such a description in the Patent-Office archives entitled the person working on such an invention to notice, during a period of one year, of the filing of an application for a patent on an interfering invention. The caveat system was abolished in 1910. In the case of Gray and Bell, a long litigation followed; and it was not until 1888 that Bell's priority was established, so far as the law was concerned, by a decision of the United States Supreme Court. Edison, at the time he filed his caveat, was not aware of the fact that his device of 1875 was crudely capable of transmitting speech; nor did he discover this until after the details of Bell's work had been made public. His apparatus has, however, a certain historical interest, notwithstanding that he always gave to Bell the credit of having discovered the transmission of articulate speech over an electric circuit by means of a vibrating diaphragm placed in front of an electro-magnet.

The next stage of the story brings us to the significant

contributions made by Edison toward the perfecting of Bell's original invention. Bell's system had no special transmitter. One contrivance, similar to the present receiver, did for both receiver and transmitter. This contrivance consisted of a steel diaphragm placed near the pole of a bar electro-magnet. The diaphragm vibrated when the tones of the voice struck it; and, acting as an armature, it induced impulses in the magnetic coil. These impulses passed over the line to the receiving station. In other words, Bell's was strictly a magneto-telephone: the sound-waves of the human voice did the work. It is hardly necessary to say that the amount of power that may thus be produced is comparatively restricted. The electric impulses on Bell's system were, therefore, decidedly faint, and hence the system could be used for none but very short lines. Indeed, Edison is himself recorded as stating that when tests were made with the Bell apparatus over Western Union wires between New York and Newark, the impulses were so feeble that not a word could be distinguished.

Now reappears Orton of the Western Union. Orton wished Edison to overcome the defects inherent in the Bell system and make the telephone thoroughly practicable. This Edison did; and then the Western Union, by acquiring the Edison patents, obtained a weapon of the utmost value to it in suits with the company that Bell had incorporated in Massachusetts.

First of all, Edison took advantage of that property of carbon by virtue of which variation in the pressure applied to it causes corresponding variation in its electrical resistance. He employed for his transmitter a closed circuit in which were two electrodes, either one or both being of carbon, and both being kept under an initial pressure, so that battery current was uninterruptedly flowing over

the circuit. One of these electrodes was connected with the vibrating diaphragm of the transmitter. Vibrations of the diaphragm caused variations in the pressure between the electrodes. Then Edison introduced an induction coil. The battery current flowed not over the line but through the primary circuit of the coil. The secondary circuit of the coil was connected with the line, over which electric impulses of very much higher potential could be sent than had been at all possible by Bell's method. Thus it will be seen that Edison made two radical changes. With his carbon transmitter (or microphone), the sound-waves of the human voice did not directly set up the electric impulses in the line, but simply varied the resistance between two electrodes, thereby operating a kind of "electric valve." Furthermore, with the induction coil the effective length of the line was greatly extended.

Almost at once these improvements of Edison's liberated the whole early art of telephony and opened up the possibilities of an instrument that many had been inclined to regard as only an interesting toy. Then began a commercial warfare between the Bell interests and the Western Union forces. A compromise was finally reached, but before that came about, the Western Union, through its subsidiary, the American Speaking Telephone company, had in operation between eighty and eighty-five telephone exchanges and was busily making apparatus. Under the terms of the compromise, the Bell company agreed to keep out of the telegraphic field and the Western Union withdrew from competition in the field of the telephone.

The Western Union was in a position to exact certain concessions, among which was a twenty per cent. royalty on the earnings of the Bell system until the Bell patents expired. From this source alone it derived until 1894

a yearly revenue of several hundred thousand dollars. This was wholly due to its ownership of the Edison patents. Dr. Alexander G. Bell died on August 2nd, 1922, at his country-house at Baddeck, Nova Scotia; and the press notices and editorials that followed his death testified pretty generally to the fact that, so far as the public mind was concerned, old controversies had passed into oblivion. Such statements as this were, however, made: "It was a long step from the first feeble voice transmitter to the present device. But the essentials are the same to-day as then, and the truly marvelous development has not been so much in the changes in the instrument itself as in the effect upon the world of its widespread use."[3] To this the objection might well be made that the essentials are *not* the same to-day as then; and that experts have declared that without the changes made by Edison, widespread telephony as we know it to-day would probably have been impossible.[4]

Edison also furnished to telephony an appliance known as the electro-motograph, the principle of which was first applied to telegraphy, and in the following manner. The sounder (or relay) was absolutely essential to long-distance telegraphy, and the operation of the sounder depended on the use of a spring to draw back the armature from the magnet. Such use of a spring was covered by a patent that had been issued only after years of delay and that was then bought by Jay Gould while he was seeking control of the Western Union. Edison succeeded, by

[3] Editorial in the "New York Tribune" of August 3, 1922.

[4] "Edison's lampblack button did not survive the test of time, but his use of *carbon* as the variable resistance proved of permanent value, and he produced a telephone transmitter of much greater power than the Bell magneto telephone."—J. A. Fleming: "Fifty Years of Electricity: The Memories of an Electrical Engineer" (London, 1921), p. 83.

means of the electro-motograph, in entirely obviating the use of a spring, and, more than that, in finding a substitute for the electro-magnet.

In place of the magnet, with its vibrating armature, he had a cylindrical piece of chalk moistened with a chemical solution and rotated by a little clockwork motor; and resting lightly against the chalk he had a diminutive pad carried at the upper end of a vibrating metal arm. The chalk cylinder was connected to one pole of a battery, the vibrating arm to the other. When no current was passing through the chalk, the pad adhered to the cylinder by virtue of frictional pressure; but when current passed through the chalk, the result was electro-chemical decomposition of the solution with which the chalk was kept moist. Thereupon the friction between the pad and the chalk was so reduced that the pad slipped, and an opposing spring at once withdrew the vibrator arm. In practice, the incoming current thus caused movements of the pad and vibrating arm corresponding to the Morse dashes and dots sent by the operator at the transmitting station. This was a wholly new method for the repetition of transmitted telegraphic signals.

After successful tests, the Western Union bought the electro-motograph. Gould, who had bought the Page patent covering a retractile spring for the armature of an electro-magnetic relay, for no better reason than to use it as a weapon in his attack on the Western Union, was suddenly brought to realize that the patent was valueless and the weapon futile. The spectacle of unscrupulous force confounded by applied science is not displeasing.

The general principle of the electro-motograph was later employed by Edison in his "loud-speaking telephone." In this contrivance, a cylinder of chalk, mois-

tened with a chemical solution, was used; and the cylinder was rotated by a crank turned by the person who received the message. Resting on the chalk was an arm faced with palladium and attached at its opposite end to a diaphragm in a resonator. The variations in the current from the transmitting station passed through the chalk cylinder, producing electro-chemical decomposition. This caused variations in the adhesion between the arm and the cylinder, and these variations in turn caused vibrations of the diaphragm. Both speaking and singing could thus be repeated with what has been described as "startling distinctness." One is inclined to think this a just description when he learns that the voice of a person talking into the carbon transmitter in New York was so amplified by the loud-speaking telephone at Menlo Park as to be heard distinctly in a field at a thousand feet from the receiver.[5]

The loud-speaker was for a time employed in England, when the telephone was being introduced there and the Bell and Edison interests were in conflict. Edison's carbon transmitter patent was sustained in the British courts against the Bell transmitter patent. The loud-speaker provided a means of escaping infringement of Bell's receiver; but it was afterward commercially discarded in favor of the Bell apparatus, which was less complicated and could be manufactured at less cost. Edison sent representatives to establish exchanges in Great Britain and on the continent. In 1879 Bernard Shaw, then a young fellow of twenty-three, was employed in the London of-

[5] ". . . It might appropriately be called 'The Shouting Telephone,' for its 'voice' is louder than that of any ordinary speaker, and we have failed to distinguish any difference in clearness of articulation between its utterances and those of a person engaged in conversation." —"Engineering" (London), March 21, 1879.

fice of the Edison company. Of this experience he discoursed most amusingly in the preface to his novel "The Irrational Knot." The loud-speaking telephone Shaw described as "much too ingenious"; it being, he said, "nothing less than a telephone of such stentorian efficiency that it bellowed your most private communications all over the house, instead of whispering them with some sort of discretion."

"This," he continues, "was not what the British stockbroker wanted; so the company was soon merged in the National Telephone Company,[6] after making a place for itself in the history of literature, quite unintentionally, by providing me with a job. Whilst the Edison Telephone Company lasted, it crowded the basement of a huge pile of offices in Queen Victoria Street with American artificers. These deluded and romantic men gave me a glimpse of the skilled proletariat of the United States; and their language was frightful even to an Irishman. They worked with a ferocious energy which was out of all proportion to the result achieved. Indomitably resolved to assert their republican manhood by taking no orders from a tall-hatted Englishman whose stiff politeness covered his conviction that they were, relatively to himself,

[6] Before the telegraphs were taken over by the British government in 1870, certain acts were passed in Parliament in 1868 and 1869, by which it was provided that inter-communication for profit by any means whatsoever should be a state monopoly. When the question subsequently arose whether, within the meaning of these acts, the telephone was a telegraph, the Post Office insisted that it was. The question having been decided in favor of the Crown, the Post Office proposed to license commercial companies on a royalty basis, the royalty to be ten per cent. of the receipts. Eventually, the telephones all came under the exclusive management of the National company referred to by Shaw. The government, however, built and owned the trunk lines. In 1911 the telephones passed into the control of the state, as the telegraphs did forty years before. See Fleming: "Fifty Years of Electricity," pp. 84, 88.

inferior and common persons, they insisted on being slave-driven with genuine American oaths by a genuine free and equal American foreman. They utterly despised the artfully slow British workman who did as little for his wages as he possibly could; never hurried himself; and had a deep reverence for anyone whose pocket could be tapped by respectful behavior. Need I add that they were contemptuously wondered at by this same British workman as a parcel of outlandish adult boys, who sweated themselves for their employer's benefit instead of looking after their own interests? They adored Mr. Edison as the greatest man of all time in every possible department of science, art and philosophy, and execrated Mr. Graham Bell, the inventor of the rival telephone, as his Satanic adversary; but each of them had (or pretended to have) on the brink of completion, an improvement on the telephone, usually a new transmitter. They were free-souled creatures, excellent company: sensitive, cheerful, and profane; liars, braggarts, and hustlers; with an air of making slow old England hum which never left them even when, as often happened, they were wrestling with difficulties of their own making, or struggling in no-thoroughfares from which they had to be retrieved like strayed sheep by Englishmen without imagination enough to go wrong.

"In this environment I remained for some months. As I was interested in physics and had read Tyndall and Helmholtz, beside having learnt something in Ireland through a fortunate friendship with a cousin of Mr. Graham Bell who was also a chemist and physicist, I was, I believe, the only person in the entire establishment who knew the current scientific explanation of telephony; and as I soon struck up a friendship with our official lecturer, a Colchester man whose strong point was pre-scientific

agriculture, I often discharged his duties for him in a manner which, I am persuaded, laid the foundation of Mr. Edison's London reputation: my sole reward being my boyish delight in the half-concealed incredulity of our visitors (who were convinced by the hoarsely startling utterances of the telephone that the speaker, alleged by me to be twenty miles away, was really using a speaking-trumpet in the next room), and their obvious uncertainty, when the demonstration was over, as to whether they ought to tip me or not: a question they either decided in the negative or never decided at all; for I never got anything."[7]

In reporting a public demonstration of the loud-speaker by Edison at Saratoga Springs, New York, in August, 1879 (on which occasion Bell sat on the platform), the "New York Tribune" said that "Mr. Edison's explanations pleased the people greatly. His quaint and homely manner, his unpolished but clear language, his odd but pithy expressions charmed and attracted them." Describing the device, the newspaper said: "The apparatus is in a small box with a crank at the side and a glass front, through which the receiver presses on the arm extending from the diaphragm to the chalk cylinder. There is a little round hole at the top of the box. The inventor showed that it made no difference in which direction the cylinder was turned, or whether it was turned fast or slow. But if he stopped turning the crank, the sound stopped the same instant."[8] It should be added that in various tests the electro-motograph successfully repeated singing at considerable distances. The loud-

[7] "The Irrational Knot" first appeared as a serial in a monthly magazine entitled "Our Corner," edited by Mrs. Annie Besant. The quotation is from the text of the American edition of 1905 (New York), pp. ix-xi.

[8] August 31, 1879.

speaking receiver used in radio-telephony is, of course, an entirely different affair.

To this same general earlier period at Menlo Park belongs Edison's tasimeter, designed to detect minute changes in temperature. The word literally signifies an instrument that measures stretching; and this term is sufficiently descriptive. In the tasimeter Edison again utilized the fact that the electrical resistance of carbon is decreased as pressure upon the carbon is increased. The instrument consisted of a strip of some material known to be very sensitive to heat—such, for example, as vulcanite, a hard variety of vulcanized india-rubber; and beneath this strip, in the order given, a platinum plate, a carbon button, and another platinum plate. The carbon button and the two platinum plates were included in an electric circuit that likewise contained a battery and a galvanometer. The minutest degree of heat caused an invisible expansion in the sensitive strip, the pressure of the strip upon the carbon button was increased, and at once a variation in the resistance of the circuit was set up. This variation the galvanometer promptly indicated. It has been stated that, with a galvanometer sufficiently delicate, the tasimeter (or microtasimeter, as it sometimes has been called) would show the action of heat from the hand of a person thirty feet distant. Edison did not seek a patent on the tasimeter, the use of which has been limited to scientific investigations, such as the study of heat from remote suns.

IX

"ORGANIZING THE ECHOES"

John Kruesi had seen Edison accomplish some pretty amazing things, but John's credulity had its limits. One day in the autumn of 1877, Edison handed to him a sketch of a model to be made as piece-work; and on the margin of the sketch was a memorandum of what Edison thought the right price for the job, $18. Kruesi set to work. He tried to figure out what such a queer affair was for; then he went to Edison and asked. When Edison had told him, he thought the whole scheme ridiculous. His business was, however, to complete the model; and so the model was completed and John stood by to see what would happen.

There was no denying that the model did look rather odd. On a wooden base a metal shaft, having a thread cut in it (like a horizontal screw) and with a handle at one end, was mounted upon two supports. The shaft ran through a metal drum, into whose surface had been cut a spiral groove. On either side of the drum was a little tube; and over the inner end of each little tube was stretched a parchment diaphragm. In the center of each diaphragm was a steel needle.

Kruesi was positive the thing would be a failure. So was Carman, foreman of the machine-shop, who (according to the accepted story) backed his opinion with the bet of a box of cigars. Edison thereupon proceeded to

act in a highly absurd manner. He put a thin sheet of tinfoil around the drum. Then he started to turn the handle of the shaft, while at the same time into one of the little tubes he declaimed in stentorian tones that immortal lyric, "Mary had a little lamb!" Then he turned the shaft backward to the starting point, drew away the first tube, adjusted the other, and once more turned the shaft forward. Out from the machine, faintly but surely, came the voice of Edison reciting the classic adventure of Mary and the lamb.

"*Mein Gott im Himmel!*" cried out John Kruesi. Carman admitted that the bet was lost. The entire staff began to collect about this marvelous cylinder whence somehow had issued the ghost of speech. Edison's own feelings may be judged by his later words: "I was never so taken aback in my life. . . . I was always afraid of things that worked the first time." The machine was the world's first phonograph. To-day it is carefully preserved in the Victoria and Albert Museum, South Kensington, London.[1]

All that night, Edison and Kruesi kept trying for better results. They learned how to fit the tinfoil more neatly to the cylinder, and how to turn the cylinder more steadily when they were making a record. Each time, as their singing or their recitation was repeated from the machine, the performance seemed astonishing. Next morning, Edison started for New York, taking the phonograph wrapped in a package. He went to the office of

[1] This follows "Mr. Edison's own account" as given in Dyer and Martin, I, 206–209 (Meadowcroft, 176–179). Numerous variants are encountered in the story as related by Edison to G. P. Lathrop and published in "Harper's" for February, 1890. See also an article by the inventor in the "North American Review" for May–June, 1878.

F. C. Beach of the "Scientific American" editorial staff. Let Beach's own narrative [2] tell what followed.

"I had not been at my desk very long that morning when Mr. Edison was announced. He came in, and set his parcel, which he appeared to handle somewhat carefully, on my desk. As he was removing the cover I asked him what it was.

"'Just a minute!' replied young Edison.

"Presently with a 'here you are,' he pushed the quaint-looking little instrument towards me. As there was a long shaft having a heavy wheel at one end and a small handle at the other, naturally I gave the handle a twist, and, to my astonishment, the unmistakable words, emitted from a kind of telephone mouthpiece, broke out, 'Good morning! What do you think of the phonograph?'

"To say that I was astonished is a poor way of expressing my first impressions, and Edison appeared to enjoy his little joke on me immensely. Like a flash the news went among the staff that Edison had brought in a machine which could talk, and soon there was an excited crowd around my desk.

"We watched the inventor wrap his little sheet of tin-foil—this was the medium used for recording the sound waves in the first machine—round the cylinder, adjust the stylus, and intently followed the operation as he shouted the lines of the nursery rhyme, 'Mary had a little lamb,' into the mouth-piece. We listened just as surprisedly when, instantly this was completed, the machine was started again and the well-known words were repeated. Time after time the machine was handled first by myself and then by my colleagues, one and all testing the instrument both in recording and reproducing.

[2] As reported by Frederick A. Talbot in the English "World's Work" (London) for October, 1911.

"Information respecting this remarkable demonstration leaked out, and in a short space of time the office was inundated with excited reporters despatched in hot haste from the various newspapers to examine the machine and witness the tests. Edison was kept going for two or three hours, but at last the crowd attained such proportions that I feared the floor would give way under the abnormal weight, and I requested the inventor to stop."

On the following day the New York newspapers carried long stories about the new mechanism, of whose principles they had but the vaguest ideas. At the time when Edison was making public his improvements in the telephone, the papers had begun to call him "The Wizard of Menlo Park"—a title that clung to him even after he had left Menlo forever. In the common thought, the phonograph made him far more of a "wizard" than ever before. Probably no other modern invention has aroused so immediate and so great a furore. An American periodical[3] referred to it as "an instrument destined to turn the old groove of every-day routine topsy-turvy"! The railway ran special trains to Menlo Park, and the laboratory was thronged with visitors. Many suspected fraud. Among them seems to have been the Rev. John H. Vincent, a bishop of the Methodist Episcopal Church and an originator, with Lewis Miller, of the "Chautauqua movement." The bishop talked into the recorder at top speed a long collection of proper names from the Bible. When these had been correctly repeated by the machine, he announced that he was now convinced there was no deception, since not another man in the country could recite the selected names with an equal velocity! The bishop had evidently supposed a ventriloquist was concealed

3 "Frank Leslie's Illustrated Newspaper," April 20, 1878.

somewhere about the premises; and this was a frequent conjecture.

Edison accepted an invitation to Washington and there put a phonograph through its paces in the apartment of Mary Abigail Dodge (better known by her pen-name, "Gail Hamilton"), a journalist, a cousin of Mrs. James G. Blaine, and author of "Twelve Miles from a Lemon." Throughout the day the rooms were thronged with folk prominent in legislative and other circles. Senator Roscoe Conkling of New York came in and was introduced to Edison, who apparently did not recognize him and who, because of deafness, did not catch the name. Edison recited into the recorder the nonsense stanza beginning "There was a little girl who had a little curl"; and the phonograph repeated it. At this, there was considerable half-suppressed merriment. Over Conkling's brow hung a prominent lock of hair, much emphasized by the caricaturists of the period; and Conkling had become highly sensitive about it. He was a rather touchy individual, and the "curl" stanza with the ensuing laughter did not please him a bit. It is possible that he may have thought Blaine, to whom he was bitterly hostile, was indirectly responsible for it. From about 11 o'clock that evening until 3:30 the next morning, Edison was at the Executive Mansion, explaining and operating the machine for the entertainment of President and Mrs. Hayes and their guests—among them Carl Schurz, who, as Edison entered, was playing the piano, as he was so fond of doing.[4]

[4] ". . . Carl went into the library and developed a new accomplishment. He played with great skill and feeling, sitting in the dusk twilight at the piano until the President [Lincoln] came by and took him down to tea. Schurz is a wonderful man. An orator, a soldier, a philosopher, an exiled patriot, a skilled musician!"—Thayer: "Life and Letters of John Hay," I, 108.

Edison at once began making a number of improved phonographs of larger size and better adapted to exhibition purposes. One diaphragm served for both recording and reproducing; and for reproducing, a horn was provided. A company was formed to manufacture machines and promote their use. The phonographs first offered for sale were made by Sigmund Bergmann in a little shop on Wooster street in New York. Bergmann had worked at the same bench with Kruesi in Newark, where his skill had attracted Edison's attention. Having saved money, he started in business for himself and was employed by Edison to manufacture not only phonographs but also carbon transmitters. Under the direction of James Redpath's once noted Lyceum Bureau (Boston), the country was parceled out in territories and the rights of exhibition within a given territory were leased on a percentage basis. In Great Britain and continental countries, manufacturing and sales rights were assigned. Prof. Fleeming Jenkin (the subject of Stevenson's "Memoir") exhibited the contrivance before the Royal Society of Edinburgh and also made use of it in scientific researches.

The phonautograph (1857) of Léon Scott has been called the "precursor" of the phonograph; and this in a certain sense it undoubtedly was, though nothing appears to have been authoritatively stated as to Edison's previous familiarity with Scott's experiments. It must be pointed out, however, that Scott's device was intended merely to make on lampblacked paper a graphic record (or tracing) of sound vibrations. This was all it could do. On December 24th, 1877, Edison filed an application for a United States patent, and on February 19th, 1878, the patent was issued. When Edison's application was being examined at the United States Patent Office, noth-

ing could be found to show that anybody had up to that time attempted what Edison had accomplished. Hence it was that the patent was issued so promptly and without a reference. The fundamental idea of the phonograph was to make phonograms ("records," they now are called) of such kind that the original sound vibrations could be *mechanically reproduced.* From the authentic account of how the machine came to be, it would seem that the working theory of the phonograph had as its starting point the idea of reproduced sound. In other words, that first crude apparatus built by John Kruesi was based on what might now appear like reverse reasoning.

"Speaking phonograph" is what the instrument was called by a staff writer in "Frank Leslie's Illustrated Newspaper";[5] and this would seem to have been an attempt to find a more nearly accurate name for it. The representative of "Frank Leslie's" visited the laboratory at Menlo Park, where Edison personally explained the phonograph and its action. "The instrument," asserts the article, "is so simple in its construction, and its workings are so easily understood, that one wonders why it was never before discovered. There is no electricity about it, it can be carried around under a man's arm, and its machinery is not a fifteenth part as intricate as that of a sewing-machine. It records all sounds and noises."

An oft-repeated story is to the effect that the invention just happened through an accident—that Edison chanced to notice that the sound waves of his voice vibrated the diaphragm of a telephone transmitter with such force that a steel point attached to the diaphragm was driven into his finger. Just how all this took place, or how it could lead in the direction of reproducing sound, is not clear.

[5] March 30, 1878.

Edison himself has explained that the phonograph had a definite beginning during experiments with the automatic telegraph. He had a revolving platen with a volute spiral groove incised in its upper surface, suggesting the disc records of to-day. On the platen he put a circular sheet of paper; and then over this sheet he passed an embossing point that was connected by an arm to an electro-magnet. When the arm was actuated by the magnet, the point embossed Morse characters on the sheet of paper. Then Edison discovered that when the sheet of paper was placed on a corresponding device having a contact point, the embossed characters were repeated and thus could be re-sent automatically and at any rate of speed.

This arrangement really dated back to the brief period (from the autumn of 1864 to February, 1865) when he was a telegraph operator at Indianapolis. At that time he was working a circuit by day, but at night he and another operator would take "press report" for the sake of the practice. Both found that they "broke" pretty often. Edison thereupon arranged two old Morse embossing registers in such a way that one recorded the characters on a strip of paper as rapidly as they were transmitted, and the other repeated them at a lower rate of speed. That is, the "press report" might be received at the rate of forty words a minute and repeated at the rate of twenty-five. By this means, Edison and Parmley, the other operator, relieved of the need for "breaking," could leisurely turn out "copy" of surprising regularity and clearness. At one o'clock in the morning, they would quit, hide away the "automatic recorder," and leave to the regular press reporter (who in the meantime had been taking a nap or perhaps attending the theater) the remainder of the report.

Under ordinary conditions the system ran smoothly—so smoothly, in fact, that the manager of the office was puzzled and the newspapers complained of inferior "copy" furnished after one o'clock. Then one night brought an uncommon pressure of work; the system fell badly behind and still the receiving instrument held to top speed. The newspapers protested, the manager investigated; the "automatic recorder" was discovered and banned.

It was this general scheme that in 1877 was applied by Edison to those experiments in automatic telegraphy to which reference has already been made. He had also been working on his carbon transmitter for Bell's telephone and studying the action of diaphragms in transmitting sound vibrations. He now observed that when the paper on the telegraphic "repeater" moved (and it could be moved rapidly enough to send several hundred words a minute), a humming note arose. Why, he queried, if indentations on paper may be made to repeat the click of a telegraph sounder, may not the vibrations of a diaphragm also be recorded and repeated? Here we have a chain of reasoning that is directly connected with the sketch Edison handed to Kruesi on that autumn day in 1877. It remains to be added that in 1879 Edison filed an application for a United States patent covering the disc principle substantially as employed to-day. Owing to certain purely minor objections, the application was held up; and the vast new detail of Edison's work in electric lighting apparently caused the matter to be neglected.[6]

The primitive phonograph turned out to be too imperfect for general use. To begin with, tinfoil was not a satisfactory material for records. It was hard to ad-

[6] A British patent obtained by him in 1878 also embodied this principle.

just and remove; the impressions made on it were faint and easily effaced. Again, the cylinder could not be turned at a strictly uniform speed, so that satisfactory records of music could not be made; and speech might be much altered in pitch, according as it was reproduced either too rapidly or too slowly. Contemporary observers also detected a certain softening of the consonants, by which the character of spoken words was appreciably affected. For several months the popular stir continued. Everywhere the exhibitions aroused great interest; royalty receipts were large. Then the craze subsided, the exhibitions ceased, and for nearly a decade the phonograph was shelved, save for such use as was made of it for scientific purposes.

Nevertheless, it remained Edison's pet invention; and in 1887 he took it from the shelf and started to eliminate its defects. Sure of its possibilities, he set out to realize them. It is said that in June, 1888, he actually worked continuously for five days and nights in his effort to develop a better instrument. This long stretch of uninterrupted labor was remarkable even for him. Some testimony to the changes he wrought in the phonograph may be found in the statement that up to 1893 more than sixty-five patents had been issued to him in connection with it; and up to 1910, more than a hundred.

For tinfoil strips he substituted hollow cylinders of specially prepared wax. This improvement was so decided that the wax-cylinder type of machine was at once established. The cylinder walls were something less than a quarter-inch in thickness, and the maximum depth of the record groove was one one-thousandth of an inch. To take the place of the needle in making the records, he designed a cutting-tool of sapphire; and for reproduction, a blunt sapphire stylus. Sapphire is a variety of

the mineral corundum and for hardness is ranked next to the diamond among precious stones. The sapphire stylus followed the record groove with a minimum of wear. Instead of the unsatisfactory adjustment screws that had been used to hold the needle in place, he added the very ingenious "floating weight," which kept both the cutting-tool and the stylus in proper engagement with the wax cylinder and prevented distortion of tone.[7] Then he altered the process of recording, making the shaft or mandrel rotate in fixed bearings while the cutting-tool travelled longitudinally (as, for example, the cutting-tool of an engine lathe does). Other changes were made—some permanently to be retained, some later to be rejected.

Of decided importance in rendering possible the commercial success of the phonograph on a large scale, was the method arrived at by Edison for making any number of copies of an original record. In the case of the tin-foil machine, attempts would appear to have been made to take a plaster cast of the original foil and thus to get impressions on other strips. With the wax-cylinder type, difficulty in obtaining a mold was at once confronted through the fact that wax is a non-conductor; hence, of course, the original record in its "first state" could not be electroplated. Edison at last got around this obstacle by the "vacuous deposit" process. The record was placed in a vacuum; and suspended on either side of the record was a piece of gold-leaf. High-tension electricity was then discharged between these gold-leaf electrodes while the record was revolved. The electricity

[7] The "floating weight" operated automatically on the principle that whereas it constantly held the stylus in contact with the varying surface of the record-groove, it was itself unable, by reason of its mass, to respond to the high-speed vibrations of the stylus but passed them along to the diaphragm.

vaporized the gold-leaf and deposited it on the record in a film so extremely thin that three hundred such would have, if superimposed, a total thickness about like that of tissue-paper; and three hundred thousand so placed would not altogether be thicker than an inch.[8] A heavier deposit of other metal could then be electroplated on this gold film. The result, after the original record had been withdrawn, was a strong, durable mold. When this mold was chilled by means of a jacket of cold water and dipped in liquefied material of a wax-like nature, a heavy deposit, forming a duplicate record, would be congealed on the chilled surface.

A company was organized in Philadelphia to introduce the "revised" phonograph commercially. This company believed that the future of the instrument lay chiefly in its use as a business appliance for all sorts of dictation without the aid of a stenographer. The fact was that the phonograph had not yet reached the stage of refinement and simplicity that later made it easily adapted, under the trade-name "Ediphone," to practical use in offices. By the first plan, the machines were leased; but renewals of the leases rarely followed. Then selling was tried and proved unsuccessful. The company failed. This time, however, the phonograph was not permitted to lapse into "innocuous desuetude." Edison took over the assets of the old company and formed a new one of his own, of which the policy was to withdraw from the business field and enter that of entertainment, especially musical. Thenceforward he devoted a great deal of energy to this enterprise, which ultimately passed into his control.

[8] When it is considered that the maximum depth of the record-groove was one one-thousandth of an inch, it will readily be seen that ordinary coatings (such, for example, as that used in the electrotyping process for making printing plates) would be far too coarse.

To this general period belonged the nickel-in-the-slot phonograph, a high box-like affair with a glass top through which, as if looking into a Swiss music-box, one could see details of the mechanism at work. It had long rubber listening-tubes, the tips of which were inserted in one's ears, giving rather the effect of a stethoscope on a grand scale. Through these were borne—thinly and squeakily, as compared with later results—fragments of music and scraps of talk.

Up to this time, the motors used to actuate the machines had been of the electric type. These were relatively heavy, rather expensive, and available only where electric current could be had. Furthermore, at that stage of development, the management and care of even small electric motors were matters too difficult for the inexpert. A substitute was found in the spring motor still in use—a mechanism relatively light, everywhere available, and practically "fool-proof."

In February, 1889, in connection with a lecture on "Edison and His Inventions" before the Franklin Institute (Philadelphia), William J. Hammer, one of Edison's ablest and most trusted assistants at Menlo Park, gave a noteworthy demonstration of how the phonograph might be combined with those other Edison inventions, the carbon telephonic transmitter (or microphone) and the "loud-speaking" telephonic receiver (or electromotograph). Phonograph records made in New York were reproduced into a carbon transmitter. The vibrations were sent to Philadelphia over 104 miles of telephone circuit, of which six were underground and underwater; received by an electro-motograph at the Philadelphia telephone headquarters and repeated into a phonograph; again reproduced into a carbon transmitter; and delivered by wire to the lecture-hall, where an electro-

motograph passed them to the audience. The sound waves travelled by means of fifteen distinct mediums; and their physical characteristics went through a series of forty-eight changes. This may justly be called an early example of "broadcasting." [9]

A writer [10] in the "Journal of the Franklin Institute" for April, 1878, thought it then impossible even to conjecture the uses to which "this wonderful instrument" might be put. Very soon afterward—in a signed article in the "North American Review" for May–June, 1878—Edison indicated the various fields in which he believed the phonograph might reveal its usefulness—"all enumerated," to use his own words, "under the head of probabilities." [11] These may thus be summarized: (a) Letter-writing and other forms of dictation; (b) records of books as read by elocutionists; (c) educational purposes (as, for example, oral instruction in languages or in elocution); (d) music; (e) family record; (f) toys, musical-boxes, etc.; (g) annunciator attachments on clocks; (h) advertising; (i) preserving the "voices as well as the words of our Washingtons, our Lincolns, our Gladstones."

"Lastly, and in quite another direction," he wrote, "the phonograph will *perfect the telephone* and revolutionize

[9] See "The Electrical Experimenter" for September, 1917. Hammer, as noted later, was prominently identified with the development of Edison's system of incandescent lighting. He afterward became a well-known electrical engineer; and during the World War was a member of the General Staff, U. S. Army, with rank of major. In a letter to the author, he stated, with reference to this demonstration, that telephone men were positive the experiment would not be successful.

[10] S. M. Plush: "Edison's Carbon Telephone Transmitter and the Speaking Phonograph."

[11] Pp. 527–536. It may be of interest to note that this issue also contained contributions from James A. Garfield, James McCosh, O. B. Frothingham, and R. W. Emerson.

present *systems of telegraphy*. That useful invention the telephone is now restricted in its field of operation by reason of the fact that it is a means of communication which leaves no record of its transactions, thus restricting its use to simple conversational chit-chat, and such unimportant details of business as are not considered of sufficient importance to record. Were this different, and our telephone-conversation automatically recorded, we should find the reverse of the present status of the telephone. It would be expressly resorted to *as* a means of perfect record." From this it is evident that Edison had even then considered the general idea of his telescribe device, which was not to be developed until long afterward and to which reference will be made later in this volume.

Of the varieties of everyday use thus indicated by Edison in 1878, the phonograph has thus far been applied with general success to four—namely, to (a) the dictation of letters that are subsequently written out on a typewriting-machine; (b) the teaching of the correct pronunciations of languages; (c) oral instruction in general, among which may be included that in calisthenic exercises; (d) the reproduction of music (with which may also be grouped spoken selections designed for entertainment). It is for the reproduction of music that most phonographs, as well as similar instruments based on the phonographic idea, are employed; and hence it is for this purpose that most of the commercial records are made. Doubtless with this fact in mind, James F. Cooke, editor of "The Étude," a popular musical magazine (Philadelphia), once declared Edison to be for our time the greatest living factor in musical advance.[12]

[12] "The Étude," October, 1923.

Yet another use,[13] perhaps dimly contemplated in 1878 but not suggested in the "Review" article, was found for the phonograph, as an essential part of the kinetophone, Edison's device for the "talking" motion-picture. The kinetophone will be treated in the proper place in a later chapter of this book. Scientists have employed the phonograph for various purposes, notably in analyzing and studying wave-forms. J. R. Hewett, editor of the "General Electric Review" (Schenectady), wrote: "This discovery is in the realm of science and the uses of the devices that can be, and have been, made by virtue of this discovery are of real scientific import as well as of great popular value." . . .[14]

In 1888, at a private exhibition of the improved phonograph in England before a distinguished gathering that included the Earl of Aberdeen, Sir Morell Mackenzie, and W. E. Gladstone, the instrument recited a "Salutation" that had been written by the Rev. Horatio N. Powers of Piermont, N. Y., and spoken into it by the author:

"I seize the palpitating air. I hoard
Music and speech. All lips that speak are mine.
I speak, and the inviolable word
Authenticates its origin and sign.

"I am a tomb, a paradise, a throne,
An angel, prophet, slave, immortal friend:
My living records in their native tone
Convict the knave and disputations end.

"In me are souls embalmed. I am an ear
Flawless as Truth; and Truth's own tongue am I.

13 See Chapter XIV, pp. 219–223.
14 "General Electric Review," April, 1924.

I am a resurrection, and men hear
The quick and dead converse as I reply."[15]

Archives for phonographic records have since been established both in this country (for example, by the Library of Congress and Harvard University) and abroad. These are intended to preserve the interpretations of vocal artists, the speaking voices of eminent persons, folk-songs, the peculiarities of local dialects, and any other records that may be thought desirable.

The original phonograph patent expired and other makers manufactured instruments of the phonographic sort, all depending, though under various trade-names, on the basic principle defined by Edison. The Edison machine had, however, come back to stay. Disc records were adopted for the cabinet phonographs; but in these records Edison adhered to his idea of a line incised to varying depths by what is known as the "hill-and-dale" method, instead of a zig-zag line of uniform depth.[16] Never completely satisfied with the results obtained in reproducing music—striving for a veritable "re-creation" as his ideal, Edison, after another period of research and experiment, developed for his disc records a new material designed to be virtually indestructible and to have a smoothness of surface that would do away with the hissing sound produced by the friction of the needle. He also originated a new recorder and a diamond-point reproducer. It was stated that laboratory tests showed such a reproducer would be unimpaired after playing more than four thousand records. Edison was constantly

[15] See Powers' "Lyrics of the Hudson," p. 69.

[16] In the gramophone (patented by Émile Berliner in 1887), the record-groove took the form of a line varying laterally instead of perpendicularly. Berliner's machine is to-day commercially known as the "Victrola."

seeking perfection, and he insisted on the utmost precision and care in all details of manufacture. " 'Throw it out!' he would say when some slight flaw in the disk records caught his ears. . . . If the disk was not perfect he would not let it go out of his factory." [17]

He also clung stoutly to the opinion that, for the best results, recording for the phonograph required of vocalists a special quality of voice and a particular technique. What he most valued was a pleasing quality in the record; and he did not think this was always best attained by the much-acclaimed artists of the opera. To Meadowcroft, his secretary, he said on one occasion that he wished "voices that will stand the test of the phonograph and give permanent pleasure to people, irrespective of stage environment, or the press agent, or pleasing personality." A writer in "The Independent" related that, having ordered some disc records to be destroyed, Edison added: "People may think some of these folks are great singers. Lots of little defects don't sound in the concert hall, but when they come out of that hole they do! They can't fool my phonograph! I've got them!" [18]

One might naturally wonder how Edison, with his pronounced deafness—so pronounced, indeed, that he could not hear at all a phonograph three feet from him—could successfully experiment with such an apparatus or could prove to be, as he did, an unsparing critic of phonographic records. "I hear through my teeth," he explained to an interviewer, "and through my skull. Ordinarily I merely place my head against a phonograph. But if there is some faint sound that I don't quite catch

[17] G. E. Walsh: "With Edison in His Laboratory," in "The Independent" for Sept. 4, 1913.

[18] Meadowcroft, 1921 ed., p. 339.——G. E. Walsh: "With Edison in His Laboratory," in "The Independent" for Sept. 4, 1913.

this way, I bite into the wood, and then I get it good and strong."[19] He thought his inner ear particularly sensitive because it had been "protected from the millions of noises that dim the hearing of ears that hear everything." It was said that he once rejected an orchestra record as defective, remarking, "The keys on that fellow's flute squeak." "Do you hear the pedal of that harp?" he suddenly asked an interviewer as a record was being tested. "I could hear no pedal," the interviewer afterward admitted, "but the Wizard's splendidly attuned ear could detect it as well as other imperfections."[20]

In 1922 the forty-fifth anniversary of the invention of the phonograph was made by Edison's associates the occasion for various informal celebrations in honor of the inventor. "Now," declared he, "I have set my heart on reproducing perfectly Beethoven's Ninth Symphony with seventy-five people in the orchestra. When I have done that, I'll quit." Forty-five years before, he had begun with that feeble, halting rendition of "Mary had a little lamb."

[19] A. L. Benson: "Edison's Dream of New Music," in the "Cosmopolitan" for May, 1913.

[20] Bailey Millard: "Pictures That Talk," in the "Technical World Magazine" for March, 1913.

X

A NEW LIGHT SHINES

In order now to resume the main course of Edison's story, we must go back to the year 1878, when the invention and exhibition of the tinfoil phonograph made so much stir. In July of 1878, Edison, who had had no real vacation in ten years, found opportunity to take one and at the same time to make a test of the tasimeter under field conditions. A total eclipse of the sun occurred on July 29th; and one of Edison's friends, Prof. George F. Barker, professor of chemistry and physics in the University of Pennsylvania, suggested that Edison accompany a scientific expedition to Rawlins, Wyoming (then Wyoming Territory), where eclipse and corona were to be observed.

Though the heat from the corona greatly exceeded the index capacity of the tasimeter used, so that no real results were obtained, yet the essential value of the instrument was manifest. After the eclipse, Edison went with a hunting party to northwestern Colorado. Having much enjoyed his glimpses of the frontier northwest, he was back at work by the end of August and was casting about for some new enterprise. Professor Barker proposed a problem in which Edison had already been interested—the problem of subdividing the electric current for illuminating purposes. Just what this involved cannot be made clear until we have briefly examined the status of electric lighting at that time.

Electric lighting was no new thing. Away back at the very beginning of the nineteenth century, Sir Humphry Davy had produced it. With his Royal Institution battery of 2,000 cells, he was able to give a large-scale display of it. At the end of each of the two battery wires he had a piece of charcoal. He brought the charcoal electrodes into contact, then separated them. At once the intervening space was filled with flame. The electrodes were horizontal and, lifted by the heated air, the flame bent upward in the form of a bow or *arc*. Davy's only source of current was the battery. For many years, batteries remained the sole available current-sources for such lights, since frictional machines gave but feeble currents and these at such high potentials as to be unadaptable. It was quite out of the question to supply current on a really large scale by means of batteries; the reason being, of course, the prohibitive cost of the materials necessary to chemical action.

In 1831 Michael Faraday discovered the principle of the magneto-machine, which converted mechanical energy into electrical energy. In the magneto-machine (present-day examples of which are widely familiar through their use in motor-cars) the modern dynamo had its beginnings. The dynamo meant relatively cheaper current, and this relatively cheaper current helped to further the introduction of the arc-light. What we now call electrical engineering had its earliest form of growth in the installation of arc-lighting for public service. Before that, applied electricity had been limited to telegraphy of various sorts and, in a small way, to electro-plating.[1]

By 1878, much had been accomplished in arc-lighting

[1] The American Institute of Electrical Engineers was not founded until 1884; and in the same year, at Philadelphia, the first American electrical exhibition was held.

both here and abroad. Plants had been installed in lighthouses on the English and French coasts. In London the light had been tried in the offices of the "Times" and on portions of Holborn Viaduct and of the Thames Embankment. Among the noteworthy sights of the Centennial Exposition at Philadelphia in 1876, were arc-lamps and the dynamo that supplied them with current. Dynamo and lamps were results of the experimental labors of William Wallace (1825–1904). Wallace, head of a large manufactory of brass and copper goods in Ansonia, Connecticut, made scientific research his hobby and was one of the pioneers of electric lighting. He it was that first built a dynamo in the United States (February, 1874); and among American manufacturers he was the first to use the dynamo in electro-plating. In his dynamo work he obtained the aid of Moses G. Farmer [2] as technical assistant; and in 1875 he began commercial production of Wallace-Farmer dynamos. Up to 1880 he continued to experiment with various types of machine, including one that is said to have been the first to employ laminated plates for the core of the armature. He invented and made (early in 1875) the first American arc-lamp—a crude affair consisting of a wooden frame on which were slotted two movable cross-bars, each holding a carbon plate. The arc, once established by a piece of carbon or wire placed in contact with the plates, followed the line of least resistance, shifting along a horizontal path between them. The adjustment device that Wallace commonly found most convenient, was a small boy who drove the plates together by hitting the cross-bars with a hammer.

[2] In the primitive days of telegraphy, Farmer had been an operator at Framingham, Massachusetts; and there in 1847–1848 he applied the principle of the telegraph to the first practicable fire-alarm.

Subsequent models of his lamp showed constant improvement. He was the first American manufacturer of arc-lamp carbons, and claimed to be the inventor of the cylindrical carbon pencil that superseded other forms of carbon electrode. With an installation of his plate lamps in the Ansonia works, he originated series arc-lighting; arc-lamps having previously been run on separate circuits. This series arrangement he never patented and it was speedily imitated. He was a pathfinder whose services are not to-day so well known as they deserve to be.[3]

Others who in this country had been devoting their attention to the development of the arc-lamp and the study of arc-lighting systems, were Elihu Thomson, Edward Weston, and Charles F. Brush. At the Mechanics' Fair in Boston in 1878, Brush exhibited a small arc-lighting dynamo that later was used in illuminating and advertising a Boston clothing-shop. Brush's lamps were placed in the public squares of Cleveland, Ohio (his native town), and in Madison and Union squares, New York.

The arc-lamp, when its carbon electrodes and its automatic adjustment had been gradually improved, was undoubtedly efficient in converting energy into light. But it had many defects. Its carbons burned rapidly away and had constantly to be replaced. As they burned, they made a hissing sound. Although the lamp's effectiveness did not extend so far as one might reasonably have supposed, yet immediately beneath the lamp the light was so intensely bright as to be unpleasant and even harmful to the eyes. Harsh shadows were cast. The

[3] See a series of articles, "William Wallace and His Contributions to the Electrical Industries," by W. J. Hammer, in "The Electrical Engineer" for February 1, 8, 15, and 22, 1893. This series is based on first-hand knowledge and is abundantly illustrated. The "History of New Haven County" (New York, 1892), edited by J. L. Rockey and others, has a sketch (vol. II, pp. 525–528).

arc flickered. It burned in an open globe; therefore, like other exposed flames, it not only consumed and fouled the air but in many places—as, for example, flour-milling plants, coal mines, and powder-works—was too hazardous to use. It could not be produced on a small scale; hence for small rooms it was impossible.

Up to 1878, it was with the arc-lamp in various forms that all "practical" electric lighting had been done. A lamp of another sort had, however, long been attempted. When the electric arc was produced, the carbons became incandescent at their tips; that is to say, heat made these tips luminous and they glowed as coals will in a grate or like the extremities of an electric fuse. This phenomenon, so readily observed, may have led to experiments with the *glow*, or *incandescent*, lamp. At all events, students of electric lighting were early aware that when current traversed a conductor possessing a high melting-point and high resistance, heat would make that conductor to some extent a source of light; and as a substance for the conductor, carbon was repeatedly tried. Refractory metals also were favored material.

As early as 1841, Frederick de Moleyns, an Englishman, took the first decisive forward step in the development of the incandescent lamp; he inclosed a metallic-wire conductor in a glass bulb from which he had exhausted most of the air. In 1845 J. W. Starr, an American, with E. A. King, an English associate, brought out a lamp in which a rod of plumbago, fastened at either end to a metallic conductor, was inserted in a barometric or Torricellian vacuum—that is, in the apparent vacuum above the mercury column in the tube of a barometer. One encounters the names of many other experimenters—such as W. E. Staite (1848) and J. J. W. Watson (1853); or Joseph W. (later Sir Joseph) Swan, who in

1860 devised a lamp with a conductor in the form of a strip of carbonized paper;[4] or Moses G. Farmer, who used (1859) platinum and iridium wire in lamps connected to primary batteries; or, coming down to 1878, W. E. Sawyer and A. Man, who in that year introduced the Sawyer-Man lamp. This had various new features, among them being an inclosing vessel charged with nitrogen gas. (Nitrogen gas is highly inert; it will not burn nor will it support combustion as oxygen does. It would therefore permit of higher temperatures than would a vacuum, at the same time assuring longer life to the conductor.) Despite these efforts, however, no inventor had yet constructed a satisfactory incandescent lamp.

Such was the general situation in the electric-lighting field when Edison, following Professor Barker's suggestion, started out to subdivide the electric current. What did this "subdividing" mean? It meant that with the same current used to light a single arc-lamp, Edison purposed to light a given number of separate or *divided* lamps, the sum of which should equal the single arc. It meant that he was to try to produce electric light in small units—in lamps of about the same candlepower as the flame of illuminating gas from an ordinary gas-jet. He saw clearly that the lamp would be the determining factor in any electric-lighting system. He saw that the arc-lamp, with its 200 or 300 candlepower, was too large and bright for the purpose he had in view. Therefore he chose the incandescent type—the type that never yet had been made to work successfully; and he was quite undeterred by the fact that experts were ready to pronounce

[4] His source of current, a battery of Grove voltaic cells, made the strip red-hot but was not powerful enough to render it fully incandescent.

subdivision an absurd notion. "The electric light," said Edison in later years,[5] "has caused me the greatest amount of study, and has required the most elaborate experiments, although I was never myself discouraged, or inclined to be hopeless of success. I cannot say the same for all my associates. And yet through all those years of experimenting and research I never once made a discovery. All my work was deductive, and the results I achieved were those of invention pure and simple. I would construct a theory and work on its lines until I found it untenable, then it would be discarded at once and another theory evolved. This way was the only possible way for me to work out the problem." . . .

In 1877, the year in which he had been working on his telephone with the carbon-button transmitter, Edison had done some experimenting (from September onward until about the end of the year) in incandescence: first with carbon strips attached to clamps forming the poles of a battery; then with refractory metals (such as boron, chromium, ruthenium), either placed directly in a circuit or inserted between carbon points. He also tried "electric candles," made by sealing into a glass tube a mixture of powdered silicon and a refractory oxide, such as lime. Carbon strips heated in open air sufficiently to incandesce, at once oxidized and crumbled to pieces. A similar strip in a vacuum produced by a hand-operated pump, remained at incandescence "for about eight minutes." Neither refractory metals nor electric candles appeared to Edison to promise anything practical. From the beginning of 1878 until the time of the eclipse expedition in July of that year, the introduction of the phonograph had claimed all his attention; but in the late summer he

[5] Arthur Churchill, "Edison and His Early Work," in the "Scientific American Supplement" for April 1, 1905.

determined at Professor Barker's suggestion to return to the lighting experiments that had been laid aside but never wholly forgotten. Thus began the long campaign for an incandescent lamp that should make subdivision of the electric current a reality.

Early in September he went to Ansonia for a personal view of what William Wallace was doing. With him went Professor Barker (who, like many other scientific men of the day, was a friend of Wallace), Charles Batchelor, Prof. Charles F. Chandler,[6] and Dr. Henry Draper. From Wallace he obtained a Wallace-Farmer dynamo and a set of Wallace arc-lamps to light the laboratory at Menlo Park. He and the other members of the party inscribed their names with a diamond-point on goblets used at that time. Edison wrote in minute script upon his goblet, long and carefully treasured by Wallace: "Thomas A. Edison, Sept. 8, 1878, made under the electric light." After a full survey of Wallace's devices and methods, Edison frankly declared: "Wallace, I believe I can beat you making electric light. I do not think you are working in the right direction." (Wallace not only was firm in allegiance to the arc-lamp, but was even experimenting with multi-carbon lamps, one such lamp of his having forty-eight pencils.) Each of these men had, however, a high regard for the other. Hammer says that Wallace often spoke in praise of Edison; and to a question of Hammer's Edison once replied that Wallace had "done a great deal of good work for which others have received the credit" and which "others have benefited largely by."[7]

[6] Chandler was at that time professor of chemistry in Columbia University. Draper was a scientist whose chief work was in the field of celestial photography.

[7] "The Electrical Engineer," February 1, 1893, p. 105.——". . . A number of very important patents taken out by inventors in this country

When Edison got back home, the first thing he did was to delve into the subject of gas lighting. He rounded up and read the back files of technical periodicals and the "Transactions" of societies of gas engineers. His laboratory notes (which, during the period of his electric-lighting researches, filled more than two hundred note-books containing a total of over 40,000 pages) included such jottings as these: "Edison's great effort—not to make a large light or a blinding light, but a small light having the mildness of gas." "Object, Edison to effect exact imitation of all done by gas, so as to replace lighting by gas by lighting by electricity." . . . "So unpleasant is the effect of the products of gas that in the new Madison Square Theatre every gas jet is ventilated by special tubes to carry away the products of combustion." There were figures giving the world's estimated investment in illuminating gas; a chart of the relative consumption of gas during the various months of the year; a prediction that gas would be used less for lighting, more for heating. Few, probably, were the gas engineers that knew the broader phases of gas illumination more thoroughly than did Edison when he had finished this preliminary survey.[8]

The facts of this method of approach have an especial interest as helping to refute popular errors regarding

which have led to expensive litigation and claims of priority by various inventors, have been given their quietus through the discovery that these inventions were anticipated by the work of William Wallace and his assistants. A notable instance is the arc lamp clutch mechanism claimed by Mr. Chas. F. Brush, found to have been first used in the Wallace lamp at the suggestion of Mr. Leroy White of Waterbury; and the claim of Mr. Edison covering the controlling of the output of a dynamo by the putting-in and cutting-out of coils in the field circuit was found to have been applied to an early Wallace dynamo used, I believe, for plating purposes." *Ib.*, February 22, 1893, p. 182.

[8] D. and M., I. 264–266; II, 604.

Edison. He has often been represented as attaining results by lucky chance; or as a sort of necromancer, with eye "in a fine frenzy rolling." Authentic evidence fails to support either view.

To provide the sinews of war, a syndicate, the Edison Electric Light company, capitalized at $300,000 was formed. Its guiding spirit was Grosvenor P. Lowrey, for many years Edison's legal adviser; J. P. Morgan, Henry Villard, and other financiers participated. Menlo Park, tiny settlement in the midst of gently-undulating farmland, was now to be for many months the scene of a driving activity that was destined to make it famous. It lay a bit west of the railway and above the level of the line—a half-dozen or so of dwelling-houses and, beyond these, the inclosure containing Edison's establishment. In the northeast corner of the inclosure was a small brick structure housing the business office on the lower floor and Edison's technical library on the upper. At the rear and southwest of this building, stood the long, two-story, frame main building. Its first floor was devoted to various purposes. Here were chemical laboratories; and here, equipped with wire connections, was a specially constructed table carrying testing instruments, portable forms of such instruments being then unknown. On the second floor was the principal laboratory—one big room in which were conducted all major experiments in connection with the incandescent electric lamp. Along the side walls of the laboratory, from floor to ceiling, ran shelves packed with containers holding a motley assemblage of chemicals and other supplies. Scattered about were batteries of cells and long tables covered with many sorts of instruments and apparatus. At the rear (or western) end was an organ that had been obtained from Hilborne Roosevelt. On this organ

Edison would sometimes "play tunes in a primitive way." [9]

Back of the main building came a carpenter-shop and the gasoline-gas outfit; and beyond was a spacious brick machine-shop, under whose roof were also engine-room and boiler. Behind the machine-shop, where Kruesi was in charge, a stretch of woods began.

It does not appear that the set of Wallace arc-lamps was ever used. The Wallace-Farmer dynamo was presumably needed for service in experiments. At any rate, while Edison was working away at his incandescent electric lamp, gasoline gas was used for artificial illumination when, as was the rule through many months, the end of day brought no respite from intensive toil.

During those early years of electric-lighting development, young men of parts and promise gathered to Edison's staff. Francis R. Upton, the chief mathematician, had studied at Princeton and later been a pupil of Hermann von Helmholtz. An associate said that "any wrangler at Oxford" would have delighted in watching Upton "juggle with integral and differential equations." The chief technician, Charles Batchelor—sometimes called "Edison's hands," had originally come from England to install thread-winding machinery in Clark's thread manufactory in Newark. Upton described Batchelor as "a wonderful mechanic" and as possessed of good judgment

[9] Hilborne L. Roosevelt (1849–1886), a cousin of Theodore, was an organ-builder well known in his day. Among the large organs he built, were that in the main building of the Centennial Exposition (Philadelphia) and those in Grace Church (New York) and the Garden City (Long Island) cathedral. "He was widely known among electricians, invented several important details of the telephone, enjoyed a royalty for many years in the telephone-switch, and was largely interested in the Bell telephone company." ("Appleton's Cyclopædia of American Biography," vol. V, p. 319.)

and untiring patience. Edison's most intimate personal friend and most valued consultant was Edward H. Johnson, who, having left the employ of the Denver and Rio Grande railroad, had already assisted Edison in long-distance demonstrations (1872) of automatic telegraphy and had been in England to represent Edison's electromotograph interests. Johnson's duties kept him away from Menlo for much of the time. Ludwig K. Boehm, Martin Force, Francis Jehl, and John W. Lawson were also associates.

Others who joined the Menlo group prior to 1881, were: William S. Andrews (like Batchelor, an Englishman), who for nearly a quarter-century held posts in various Edison companies and later became a consulting engineer of the General Electric company; William J. Hammer, who had been assistant to Edward Weston in Weston's malleable-nickel works in Newark and who afterward, besides rendering Edison important and confidential services both at home and abroad, was allied with Frank J. Sprague in installing at Richmond, Virginia, the world's first large-scale electric-traction line (1887); John W. Lieb, in after years vice-president of the New York Edison company, who began at Menlo as a draughtsman; Charles L. Clarke, who subsequently was appointed chief engineer of the Edison Electric Light company in New York and in time became, like Andrews, one of the General Electric company's engineers; and Edward G. Acheson, who in 1891 invented the abrasive carborundum (silicon carbide) and the carborundum furnace.[10] Dr.

[10] Acheson was using the electric furnace in experiments to make artificial diamonds and accidentally hit on carborundum. Carborundum is used in place of corundum or emery for polishing or sharpening. It is the result of the action of carbon on silicon at high temperature; coke powder supplying the carbon, and sand the silicon, while sawdust and ordinary salt (sodium chloride) are used to facilitate the process.

Edward L. Nichols, after study at the universities of Leipzig, Berlin, and Göttingen and a fellowship at Johns Hopkins, was at Menlo doing special scientific research for Edison during the winter of 1880–1881. He was professor of physics in Cornell University from 1887 to 1919 and published several text-books.

Batchelor, Upton, and Edison had houses of their own. Edison's place was distinguished by a windmill that pumped water for the household reservoir. Close at hand was Mrs. Jordan's boarding-house for Edison employees. In the experimental work, according to Edison's account, "we had all the way from forty to fifty men." [11] "They worked," he continues, "all the time. Each man was allowed from four to six hours' sleep. We had a man who kept tally, and when the time came for one to sleep, he was notified." Said Francis Jehl: "It often happened that when Edison had been working up to three or four o'clock in the morning, he would lie down on one of the laboratory tables, and with nothing but a couple of books for a pillow, would fall into a sound sleep. . . . Some of the laboratory assistants could be seen now and then sleeping on a table in the early morning hours." Small wonder that R. U. Johnson, who several times visited Menlo during this period, has written: [12] "It was a time of great intensity, every one being keyed up to concert pitch." Upton once commented: ". . . I have often felt that Mr. Edison could never comprehend the limitations of the strength of other men, as his own physical and mental strength have always seemed to be without limit. He could work continuously as long

The crystallized carborundum is nearly as hard as a diamond; sulphuric acid and other extremely powerful acids do not affect it.

[11] D. and M., II, 634.

[12] "Remembered Yesterdays," p. 115.

as he wished, and he had sleep at his command."[13]

Not only was Edison possessed of great physical stamina, but he was also inured to night-work through his experience as a telegraph operator. A favorite dogma of his was that we sleep too much. He was perhaps too ready to suppose that all other men had similar physiques or could adapt themselves to his methods. There is record of his enthusiastic praise of a man whom he chose to run one of his Newark shops. "When in need of rest," said Edison, "he would lie down on a work-bench, sleep twenty or thirty minutes, and wake up fresh. *As this was just what I could do,*[14] I naturally conceived a great pride in having such a man in charge of my work." It has been written of him that he "never hesitated to use men up as freely as a Napoleon or Grant; seeing only the goal of a complete invention or perfected device."[15] . . . Yet Francis Jehl declared[16] that Edison's "winning ways and manners" made the laboratory-workers at Menlo "ever ready with a boundless devotion to execute any request or desire"; that Edison "was respected with a respect which only great men can obtain." This probably reflects the sentiments of the majority. Most of the assistants were young men, enthusiastic and at the beginning of their careers. They believed in themselves; they believed in their chief; and, though sometimes discouraged, they believed in the future of the art they were helping to evolve.

When the staff was working late, a midnight meal was brought in, supplying excuse for a pause in the night's occupation. Now and then some of the men from the

[13] D. and M., I, 281.

[14] *Ib.*, I, 140. The italics are ours.

[15] *Ib.*, I, 134–135.

[16] *Ib.*, I, 297.

office were present on these occasions; sometimes old acquaintances of Edison's joined the circle; often the meal would be followed by music—noisy choruses, an organ "selection," a vocal solo by Boehm (who played his own accompaniment on a zither) or somebody else. Save for these intervals, we hear of but one officially-recognized form of relaxation. "During the summer-time," said Edison, "after we had made something which was successful, I used to engage a brick-sloop at Perth Amboy and take the whole crowd down to the fishing-banks on the Atlantic for two days." [17] Edison had the patience necessary to the complete angler. Once, inside Sandy Hook, he fished without a bite for two days and two nights and then quit only because the other members of the party compelled him to by raising anchor and sailing away.

For the long train of experiments now undertaken to achieve a satisfactory lamp as the prime requisite of subdivision of the electric current, Edison naturally returned to his earlier researches as a starting-point. To be satisfactory, the lamp would have to meet successfully both scientific and commercial tests. Scientifically, it must have an incandescing substance with high resistance and small radiating surface, and capable of sustaining for a thousand or more hours a temperature in excess of two thousand degrees. Commercially, it must be proof against the ordinary impacts of daily use; simple to manage; cheaply produced; and permitting the maximum economy in the outlay for copper wires to bring current to it. Furthermore, as part of a system intended eventually to supplant gas for illuminating purposes, it must be independent of every other lamp on the circuit—that is, it must be so arranged that it could be lit or extin-

[17] D. and M., II, 634.

guished without reference to any other lamp, just as gas could be at the individual jet. And the lamps must be units of a system that could be operated at charges reasonable enough to make it a real competitor of gas.

In order that the lamps should be independent of each other, it was necessary to run them in "multiple circuit." They could not be run in "series." "Multiple circuit" and "series" are the terms used for the leading two systems of distributing electric current for general use. To gain a rough idea of the series system, one may regard it as a big loop or ellipse-like arrangement on which all the lamps are directly carried. The current acts, therefore, along the path of the loop, and to reach the successive lamps it must pass through the preceding lamp or lamps; that is, to reach, say, the fourth lamp it must pass through the first, second, and third; and to reach the last lamp of the circuit it must pass through all the others. Hence, if one lamp were out of order, the path would be broken and the current interrupted; for, in order that an electric current may flow, the circuit must be "closed" or "made" throughout, either wholly along the route of a wire conductor or with the earth as a "return." In the series system, the lamps are, to borrow an apt comparison, "like beads on a string, and therefore not independent of one another, but all dependent on the integrity and continuity of the circuit or string." [18]

Now, the multiple-circuit system may be rudely represented as a ladder. The sides of the ladder are two parallel conductors, one positive and the other negative. The rungs of the ladder are the circuits of the individual lamps, each lamp having its own rung. Thus each lamp is connected by one electrode (or pole) to the positive

[18] Address of J. W. Lieb before the Edison Pioneers, February 11, 1920 (Edison's seventy-third birthday).

conductor, by the other to the negative. If one rung is broken—that is, if one lamp is out of order, the sides and the other rungs remain intact—that is, the parallel conductors continue to function and so do the other lamp-circuits and lamps. This will make it sufficiently clear that for a distribution such as Edison had in mind, in which electric light was to be provided in small independent units as gas light was, the multiple-circuit system was inevitable.

The individual lamp to be used with such a system must, as has already been said, have an incandescing substance of small cross-section (or radiating surface) and high resistance. The reason for this is readily grasped. Incandescence was, of course, to be obtained from heat produced by the action of the current in passing through the incandescing substance. The resistance of a conductor is inversely proportional to its cross-sectional area. Therefore the resistance offered by the incandescing substance (or burner) must be greater than that offered by the wires bringing the current from the source of supply; for, if the reverse were true, heat needed in the burner would be wasted in the wires. Yet Edison's predecessors had worked in the opposite direction—that of burners with large cross-section (or radiating surface) and low resistance. With relation to the resistance of the burner, it was necessary to consider the voltage (or electromotive force) of the current—voltage being comparable to pressure or "head" in hydraulics. The electromotive force must be relatively high, the current-flow relatively small. The higher the voltage,[19] the greater would have to be the resistance of the burner. The lower the voltage, the

[19] The volt is the working unit-of-measure of electromotive force; being such an electromotive force as will convey a current of one ampere against a resistance of one ohm.

greater would have to be the size of the wires supplying the current.

On the ascending scale, a point would be reached where it would be virtually impossible to provide a burner with adequate resistance. On the descending scale, a point would be reached where the amount of copper for wires would be so large as to make prohibitive the cost of commercial manufacture. In other words, the current must be of a voltage high enough to render commercial installation feasible, but not so high as to make light by incandescence a vastly difficult thing to attain; and the burner must be of a cross-section small enough to offer adequate resistance, yet not so small that the material used would be unstable and short-lived.

Facing such difficulties at the outset, Edison renewed his attempts with carbon strips, of which he made "a very large number of trials."[20] The strips were of carbonized paper, and this was also tried in a great variety of other forms. Wood carbons and hard carbon (as in the arc-lamp) were put to the test. So were sticks (or wires) of paper tissue that had been coated with lamp-black and tar, then rolled out thin and carbonized. These burners, in such vacuum as Edison was able to create with an ordinary air-pump, lasted only ten or fifteen minutes. Edison had been inclined to select carbon as the most promising substance for incandescence, but there was no denying that, even under the best conditions he could then furnish, it was not practicable; so, for the time being and reluctantly, he abandoned it. Then he again took up refractory metals.

The resistances of platinum and of iridium, a silver-whitish metal of the platinum group, were known to be relatively high. Edison therefore made wire burners of

[20] D. and M., I, 249.

iridium, of platinum, and of refractory alloys, and these he experimented with both in the open air and in the best vacua he could get with the same common type of air-pump that he had used in the case of the carbon burners. When incandescent, the metal wires showed, it is true, a longer life than had the carbon burners; but the current required to bring them to incandescence was so powerful as to melt them in a short time. To control the temperature of the wires and thus to keep them from being melted, Edison introduced regulating devices into the circuit; but these devices proved to be unreliable.[21] He next coiled platinum around a bobbin of refractory oxide—still without the results he sought. In connection with these investigations, he made, on the evidence of one of his note-books, some 1,600 different tests of earths, minerals, and ores.[22]

In the spring of 1879, metallic-wire lamps were privately exhibited at Menlo to members of the syndicate. Several lamps with platinum burners were "hooked up" in series in the machine-shop; current being furnished, according to Francis Jehl, by a dynamo "of the Gramme type." [23] The exhibition was not enheartening. Current was turned on. "A little more juice," said Edison to Kruesi; and a second time, "A little more." For a fleeting moment one lamp gave forth "a light like a star in the distance." Then followed an explosion—a puff—darkness! Batchelor removed the wrecked lamp; in-

21 In one type, the current was led through a metal bar that, when the current became too strong, acted as a shunt or short-circuit. In another, expansion of gas or air inclosed in a tube operated a diaphragm that worked in similar fashion.

22 D. and M., II, 605–606.

23 D. and M., I, 289. This was presumably the Wallace dynamo. Wallace built dynamos of various types. His first machine and the one used at the Centennial Exposition had Gramme-ring armatures. See Hammer's article in "The Electrical Engineer" for February 8, 1893.

serted a fresh one. The same thing happened. One or two more trials were made, with like finale. "After that exhibition," commented Jehl, "we had a house-cleaning at the laboratory." . . .

Nevertheless, Edison was making progress. First, he had learned that the incandescing substance must be hermetically inclosed in a container (now known as a "bulb") formed entirely of glass and exhausted of air as thoroughly as possible. Thus inclosed, his platinum wire would yield, without melting, a light of twenty-five candles, whereas in the open air it would melt while yielding but four candles. Second, he had learned that when the air was being pumped out, a current must be sent through the incandescing substance. He noticed that, even with high vacua, oxygen appeared to be present to a perplexing extent, hastening the destruction of his platinum wire. This oxygen, he reasoned, must be held in the material of the wire when the wire was sealed into the glass; perhaps, if the wire were kept aglow while pumping was under way, the oxygen might be driven from the wire, whereupon it would be pumped out as the free air was. Tests showed his reasoning was correct.

He now returned to carbon, and returned to stay, taking with him his invaluable new knowledge. In the case of carbon, it was realized that the importance of passing a current through the burner while a vacuum was being produced was even greater than in the case of the metal wires; for carbon in its more porous states has a marked property of absorbing (or occluding) gases—a common example being afforded by charcoal, which by virtue of this property is of help in preserving foods. Through his experiments with platinum, Edison had learned something else: though platinum had a melting-point relatively too low for his purpose, and though it was inferior

in light-giving quality, yet it was long to play an essential part in the construction of incandescent lamps. For it was found to have the same coefficient of expansion as glass had; hence it was used as the material of the "leads," the wires that respectively brought current to the lamp and conveyed it from the lamp. Consequently no gaps developed to cause leakage at the points where the wires were sealed into the glass. Leads were made of platinum for many years, but platinum was costly and search was therefore begun for a substitute, which luckily was discovered through the use in combination of two metals whose joint coefficient of expansion was of proper value.

From the date of the invention of the phonograph, Edison had been regarded by the gentlemen of the press as a likely source of "copy." It was not long before the objective of his new labors became known. He believed, so it transpired, that the electric current could be subdivided; more than that, he was proposing to subdivide it. If outside of the Menlo Park organization and a few of Edison's friends, like Professor Barker, there were experts either at home or abroad who agreed with him in belief or who anticipated a successful outcome for his experiments, they neglected to say so. On the contrary, William H. (later Sir William) Preece, a distinguished English electrician, somewhat contemptuously declared, ". . . The subdivision of the light is an absolute *ignis fatuus*"; thus supplying a catch-phrase that was to return boomerang-like upon its inventor. A committee of the House of Commons met, with Dr. Lyon Playfair (later Baron Playfair of St. Andrews) as chairman, to take counsel upon the matter of electric lighting; but its report dismissed Edison with short shrift indeed.[24] More

[24] See D. and M., I, 242; T. C. Martin, "Forty Years of Edison Service" (New York, 1922), pp. 3–4.

graciously, more judicially, but hardly more hopefully, the famed John Tyndall said in a lecture before the Royal Institution: "Edison has the penetration to seize the relationship of facts and principles and the art to reduce them to novel and concrete combinations. Hence, though he has thus far accomplished nothing new in relation to the electric light, an adverse opinion as to his ability to solve the complicated problem on which he is engaged would be unwarranted. . . . Knowing something of the intricacy of the practical problem, I should certainly prefer seeing it in Mr. Edison's hands to having it in mine." [25] Others were much less courteous and reserved. " 'Dreamer,' 'fool,' 'boaster' were among the appellations bestowed upon him by unbelieving critics. Ridicule was heaped upon him in the public prints, and mathematics were [*sic*] called into service by learned men to settle the point forever that he was attempting the utterly impossible." [26]

Meanwhile, Edison was cultivating his garden. Of all substances, carbon has the maximum fusing-point (7000 degrees F., equivalent to about 3900 degrees C.); but this advantage alone was not enough. Carbon must, for Edison's purpose, be formed into a homogeneous, stable burner of properly tenuous cross-section. More than a quarter-century later, Edison, speaking in a general way of the obstructions encountered, had this to say: "Just consider this; we have an almost infinitesimal fila-

[25] F. M. White, "Edison and the Incandescent Lamp," in "The Outlook" for February 26, 1910. Also, "Forty Years of Edison Service," pp. 3–4; D. and M., I, 243. In the "Fortnightly Review" (February, 1879) Tyndall remarked, "Though we have possessed the electric light [*i.e.*, the arc light] for seventy years, it has been too costly to come into general use." He added his belief that electricity would in time "illumine our streets, halls, quays, squares, warehouses, *and perhaps at no distant day, our homes*." (The italics are ours.)

[26] D. and M., II, 713–714.

ment heated to a degree which it is difficult for us to comprehend, and it is in a vacuum, under conditions of which we are wholly ignorant. You cannot use your eyes to help you in the investigation, and you really know nothing of what is going on in that tiny bulb. I speak without exaggeration when I say that I have constructed three thousand different theories in connection with the electric light, each one of them reasonable and apparently likely to be true. Yet in two cases only did my experiments prove the truth of my theory. My chief difficulty was in constructing the carbon filament, the incandescence of which is the source of the light." [27]

Edison persistently studied not only carbon as luminous material but also high vacua and the means for obtaining them in an increasingly suitable degree. By about October 1st, 1879, he had a pump that was capable of creating a vacuum as high as one one-millionth part of an atmosphere. "If he [Edison] wanted material," wrote Francis Upton, "he always made it a principle to have it at once, and never hesitated to use special messengers to get it. I remember in the early days of the electric light he wanted a mercury pump for exhausting the lamps. He sent me to Princeton to get it. I got back to Metuchen late in the day, and had to carry the pump over to the laboratory on my back that evening, set it up, and work all night and the next day getting results." [28] Finally it occurred to Edison, still vainly pondering a carbon conductor that should be small enough and durable enough, to see what might be done with cotton sewing-thread. Of a compacted, fibrous structure and certainly with a small cross-section, this might when carbonized turn out to be the very thing.

[27] Arthur Churchill, "Edison and His Early Work," in the "Scientific American Supplement" for April 1, 1905.

[28] D. and M., I, 299.

For carbonizing, a short piece of the thread, bent into hairpin shape, was placed in a nickel mold, and then the mold was allowed to remain for five hours in a muffle-furnace. After the mold was removed from the furnace and became cool, it was opened; and then the carbon phantom of thread had to be withdrawn from the mold and sealed into a bulb. It was a task of fortitude and delicacy. All night, the next day, and another night, Edison and Batchelor kept at it. From a whole spool of thread, they finally succeeded in getting a carbonized piece that did not break while being taken from the mold. . . . "It was necessary," Edison related, "to take it to the glass-blower's house.[20] With the utmost precaution Batchelor took up the precious carbon, and I marched after him, as if guarding a mighty treasure. To our consternation, just as we reached the glass-blower's bench the wretched carbon broke. We turned back to the main laboratory and set to work again. It was late in the afternoon before we had produced another carbon, which was again broken by a jeweller's screw-driver falling against it. But we turned back again, and before night the carbon was completed and inserted in the lamp. The bulb was exhausted of air and sealed, the current turned on, and the sight we had so long desired to see met our eyes." The date was October 21st.

That lamp continued at incandescence for more than forty hours, while Batchelor, Edison, and others watched it and bets were laid as to how long it was going to burn.

[20] H. A. Jones, "Thomas Alva Edison," p. 106. The glass-blowing was at that time done by the aid of gasoline gas in a "small building on one side of the laboratory" (D. and M., I, 272). Manufacture of incandescent lamps was later carried on in an old wooden building on the other side of the railway tracks. The little structure in which was blown the first glass for Edison bulbs is preserved at the lamp works of the General Electric company at Harrison, New Jersey.

Then the light failed. But the sewing-thread lamp had rendered its reasonable service and won a place in the story of modern invention. It had shown that carbon would sustain temperatures before which platinum would quickly melt; that subdivision of the electric current was truly possible. Some thirteen months had passed in experiments and more than $40,000 had been spent; but Edison and Batchelor now doubtless felt that the expenditure of time and money had been justified. As for Batchelor, it may be doubted whether anybody else at Menlo—even Edison himself—could have accomplished what he accomplished with that brittle filament.

Nevertheless, those forty hours, although they established a principle, did not answer to the commercial requirements for a stable burner. Forthwith Edison inaugurated the most whole-hearted carbonizing-bee on record. Among the things he carbonized were:

bagging
baywood
boxwood
cardboards of many kinds
cedar shavings
celluloid
cocoanut hair
cocoanut shell
cork
cotton soaked in boiling tar
drawing-paper in great variety
fish-line
flax
hickory
lampwick
maple shavings
paper saturated with tar
plumbago (graphite)
punk
red hairs from the beard of J. U. Mackenzie (who was staying at Menlo)
threads, cotton and linen, of all sorts
threads of fine size, plaited
threads treated with tarred lampblack
tissue-paper
twine
vulcanized fiber
wood-splints

One of the very early types of incandescent lamp was that having a spiral filament of tar and lampblack kneaded and rolled into a kind of paste or putty-like mixture. Edison once directed a member of the laboratory staff to make up a quantity of this paste and bend it into filaments. By and by the assistant carried the stuff to Edison.

"There's something wrong about this," he complained, "for it crumbles." . . .

"How long," asked Edison, "did you knead it?"

"Oh," said the assistant, "more than an hour."

"Well," replied Edison, "just keep on for a few hours more and it will come out all right."

Which, sure enough, it did. It is stated that filaments with a cross-section of but 7/1,000 of an inch were rolled from material of this kind.[30]

Of all the substances tested during this period, paper, however, appeared the most likely—so likely, indeed, from the more strictly commercial viewpoint, that Edison started the regular manufacture of lamps with looped filaments of carbonized paper. Scores of these were put into service, not merely within the laboratory but also in dwellings at Menlo and along the neighborhood roads. Doubters might cavil and wiseacres argue: folk travelled to the spot and went away to report that a new light was actually burning there.

On the morning of December 21st, 1879, Albert E. Orr, city editor of the "New York Herald," was at his desk in

[30] D. and M., II, 610–611. Acheson made for Edison 16,000 filaments cut from sheets of graphite that had been subjected to hydraulic pressure of one hundred tons. He contracted to make 30,000 but quit because they turned out to be inefficient. They "produced a magnificent light, but they did not last long in use, disintegrating rapidly" (Acheson's "My Days with Edison," in the "Scientific American" for February 11, 1911; p. 143).

the "Herald" office (then at the corner of Ann street and Broadway). Of a sudden, in rushed Thomas B. Connery, the paper's managing editor, and spread accusingly upon the desk a copy of that day's sheet. Orr looked up in natural surprise, for Connery did not usually appear at the office until two or three hours later.

"How," demanded Connery, "did that stuff get into the paper, Mr. Orr? Lights strung on wires, indeed! You've made a laughing-stock of the 'Herald'! Oh, what *will* Mr. Bennett say!"

"He'll probably say," Orr answered calmly, "that it is the biggest newspaper beat in a long time."

Connery was pointing at a full-page story about Edison's incandescent lighting.

"But don't you know," he continued in a plaintive tone—"don't you *know* that it has been absolutely demonstrated that that kind of light is against the laws of nature? Who wrote the article?"

"Marshall Fox."

Fox was classed among the "star" reporters of New York's newspaperdom. He had represented the "Herald" on the eclipse expedition to Wyoming in the previous year.

"How could he," protested the managing editor, "have allowed himself and the paper to be imposed upon so? Where is he? Send for him. We must do something to save ourselves from ridicule. . . . No—don't try to explain—just find Fox and send him to me."

With that, Connery flung out of Orr's office and into his own, determined to know how it befell that one of his most trustworthy men had been so grossly credulous.[31]

[31] See F. M. White, "Edison and the Incandescent Lamp," in "The Outlook" for February 26, 1910.

Far from bringing ridicule upon the "Herald," Fox's article aroused such interest that it was decided to have a formal public exhibition. This was held at Menlo on New Year's Eve, 1879. The railway ran special trains, and more than 3,000 visitors, including many persons of prominence, made the trip to view the strange, brilliant glow-lamps hanging on wires stretched from one leafless tree to another.[32]

By January 10th, 1880, Edison's doings had evidently been more fully accepted in editorial offices, for we find "Frank Leslie's" of that date enthusiastically explaining to its readers:[33]

". . . Edison's electric light, incredible as it may appear, is produced from a little piece of paper—a tiny strip of paper that a breath would blow away. Through this little strip of paper is passed an electric current, and the result is a bright, beautiful light, like the mellow sunset of an Italian Autumn. He has made this little piece of paper more infusible than platinum, more durable than granite[!]. And this by no complicated process. The paper is merely baked in an oven until all the elements have passed away except its carbon framework. The latter is then placed in a glass globe connected with the wires

[32] "Possibly events might have happened differently had Edison been able to prevent the announcement of his electric-light inventions until he was entirely prepared to bring out the system as a whole, ready for commercial exploitation, but the news of his production of a practical and successful incandescent lamp became known and spread like wildfire to all corners of the globe. It took more than a year after the evolution of the lamp for Edison to get into position to do actual business, and during that time his laboratory was the natural Mecca of every inquiring person. Small wonder, then, that when he was prepared to market his invention he should find others entering that market, at home and abroad, at the same time, with substantially similar merchandise."—D. and M., II, 714–715.

[33] Pp. 353–354.

leading to the electricity-producing machine, and the air exhausted from the globe. Then the apparatus is ready to give out a light that produces no deleterious gases, no smoke, no offensive odor—a light without flame, without danger, requiring no matches to ignite, giving out but little heat, vitiating no air, and free from all flickering. And this light, the inventor claims, can be produced cheaper than that from the cheapest oil."

The article thus describes how the lamps were made:

"The paper carbons are prepared quite simply. With a suitable punch there is cut from a piece of 'Bristol' cardboard a strip of the same in the form of a miniature horseshoe, about two inches in length and one-eighth of an inch in width. A number of the strips are laid flatwise in a wrought-iron mold about the size of the hand, and separated from each other by tissue-paper. The mold is then covered and placed in an oven, where it is gradually raised to a temperature of about six hundred degrees Fahrenheit. The mold is then placed in a furnace and heated almost to a white heat, and then removed and allowed to cool gradually. On opening the mold the charred remains of the little horseshoe cardboard are found. After being removed from the mold it is placed in a little globe and attached to the wires leading to the generating machine. The globe is then connected with an air pump, and the latter is at once set to work extracting the air. After the air has been extracted the globe is sealed, and the lamp is ready for use."

"Scribner's Monthly" for February, 1880, contained an article by Upton entitled "Edison's Electric Light" and indorsed by Edison as "the first correct and authoritative account."[34] Upton's scientifically trained mind is evidenced not merely in the treatment of detail but in

[34] Pp. 531–544.

the following generalized remark: "Besides the enormous practical value of the electric light, as domestic illuminant and motor, it furnishes a most striking and beautiful illustration of the convertibility of force. Mr. Edison's system of lighting gives a completed cycle of change. The sunlight poured upon the rank vegetation of the carboniferous forests, was gathered and stored up, and has been waiting through the ages to be converted again into light. The latent force accumulated during the primeval days, and garnered up in the coal beds, is converted, after passing in the steam-engine through the phases of chemical, molecular and mechanical force, into electricity, which only waits the touch of the inventor's genius to flash out into a million domestic suns to illuminate a myriad homes."

But if the cotton-thread lamp had not satisfied its inventor, neither, in spite of its comparative success, did the paper lamp. Although he was in a limited way manufacturing lamps of that sort, yet he was unceasingly prospecting for something better—exploring with a microscope this specimen and that. When he started in to carbonize pretty nearly everything that lay around loose, he not only experimented with the materials listed above but also studied and tried certain grasses, canes, and similar vegetable growths. In the laboratory one day—it was "in the early part of 1880"—he picked up a palm-leaf fan and examined it. Palm-leaf fans were objects common enough, but never before had he looked at one so carefully. He saw that the edge of the fan was bound with a long, thin, flexible strip of bamboo. This strip he tore from its moorings and gave to an assistant, with directions to divide it into the largest possible number of pieces suitable for carbonizing into filaments. When tried, these filaments proved markedly successful

—much superior to anything else employed up to that time; so superior that here, he judged, was the very stuff for a practicable lamp. Yet not exactly that—characteristically, he was sure that the world must hold a bamboo still more fit; possibly (who could tell?) the perfect bamboo for his use; or else a palm or other plant that would surpass any bamboo.

Then followed the adventurous episodes of the fiber-hunt. From time to time, for the greater part of a decade, men were sent out to comb various tropical regions in the quest for the elusive material. They were instructed in the *minutiæ* of drawing and carbonizing fibers, and took with them a set of implements by means of which tests could be made in the field. As they travelled, they shipped to Menlo bale after bale of the more worthwhile specimens they had collected. Each specimen was put through most thoroughgoing laboratory tests. It has been reckoned that, from first to last, Edison carbonized and tried as filaments in lamps the fibers of as many as 6,000 distinct species of plants—chiefly bamboos. (For bamboo filaments, sections running "with the grain" were taken from the rim of the stem, immediately beneath the epidermis.) In his pursuit of "the things that are more excellent," he spent approximately $100,000.

Inasmuch as China and Japan were known to possess an extensive assortment of bamboos, it was to those countries that the first representative went. He was William H. Moore, and he started for the Orient in the summer of 1880. He made his way into the far interior of both Japan and China, encountering many obstacles and sometimes being at first received in a not wholly friendly manner by the natives. From the quantity of specimens he obtained, a certain kind of Japanese bamboo was chosen as the best material yet tried for filaments. A contract

was forthwith made with a Japanese farmer to supply this; and so skilful was he in the growing of it that he steadily improved it in quality. For years, Edison lamp filaments were manufactured from these particularly homogeneous fibers.

On the far side of the world, bamboo had long been the chief natural resource. To a degree that most Occidentals probably do not appreciate, this grass of the field —for it is a grass—had conditioned human existence. A. B. Freeman-Mitford (Baron Redesdale) has eloquently detailed the supreme value of bamboo to a Japanese or a Chinaman.[35] ". . . It furnishes the framework of his house and thatches the roof over his head, while it supplies paper for his windows, awnings for his sheds, and blinds for his verandah. His beds, his tables, his chairs, his cupboards, his thousand and one small articles of furniture are made of it. Shavings and shreds of bamboo are used to stuff his pillows and his mattresses. The retail dealer's measures, the carpenter's rule, the farmer's water-wheel and irrigating pipes, cages for birds, crickets, and other pets, vessels of all kinds, from the richly lacquered flower-stands of the well-to-do gentleman down to the humblest utensils, the wretchedest duds of the very poor, all come from the same source. The boatman's raft, and the pole with which he punts it along; his ropes, his mat-sails, and the ribs to which they are fastened; the palanquin in which the stately mandarin is borne to his office, the bride to her wedding, the coffin to the grave; the cruel instruments of the executioner, the lazy painted beauty's fan and parasol, the soldier's spear, quiver, and arrows, the scribe's pen, the student's book, the artist's brush and the favourite study for his sketch; the musician's flute, mouth-organ, plectrum, and a dozen various

[35] In "The Bamboo Garden" (London, 1896), pp. 29–30.

instruments of strange shapes and still stranger sounds—in the making of all these the Bamboo is a first necessity. Plaiting and wicker-work of all kinds, from the coarsest baskets and matting down to the delicate filigree with which porcelain cups are encased—so cunningly that it would seem as if no fingers less deft than those of fairies could have woven the dainty web—are a common and obvious use of the fibre. The same material made into great hats like inverted baskets protects the coolie from the sun, while the labourers in the rice fields go about looking like animated haycocks in waterproof coats made of the dried leaves of Bamboo sewn together. See at the corner of the street a fortune-teller attracting a crowd around him as he tells the future by the aid of slips of Bamboo graven with mysterious characters and shaken up in a Bamboo cup, and every man around him smoking a Bamboo pipe. See in yonder cook-shop the son of Han regaling himself with a mess of Bamboo shoots, which have been cooked in a vessel of the same material coated with clay, and are eaten with chopsticks which may have grown on the same parent stem. Such shoots, either in the shape of pickles or preserved in sugar, are an article of export from south to north where they are esteemed a delicacy."

For this marvelous vegetable, Edison had disclosed a new function. Modifying it by heat, he discovered in it new properties. Servant of man from primitive ages, it now became an adjunct to modern science.

In December of 1880, John C. Brauner, a man already considerably familiar with the South American flora, sailed for Para, Brazil. On foot and by canoe he travelled some two thousand miles through the swamps and forests of lower Brazil and along its rivers, in a region then practically unknown to white men. He collected a

great number of specimens of grasses and palms, but found nothing that was to be preferred to Moore's Japanese bamboo.

To Cuba went Segredor, one of the laboratory workers. Segredor had once caused rather a flurry at Menlo. Some of the others thought it amusing to tease him. At last he said to the force, "The next man that does it, I will kill him"; but they did not take this seriously. Next day, a taunt was cast at him and he hurried from the laboratory. In a few moments he was seen coming up the slope from his boarding-house, carrying a gun. Then the laboratory folk ran to cover of the woods—all but one, who finally succeeded in pacifying him. Quiet was restored, but nobody deemed it wise to badger Segredor after that. Now he was sent to Cuba to look for fiber. He landed at Havana only to die of yellow fever before the week was out. "On the receipt of the news of his death," said Edison, "half a dozen of the men wanted his job." . . . No one else was sent, however, as it was believed that the chances of finding superior bamboo in Cuba were not particularly favorable. Search was also made in Florida for palmettos, in Jamaica for bamboos; but none of the palmetto fibers was up to test; and of the bamboo fibers, none equalled the Japanese kind that already was exclusively used for Edison's commercial production of lamps. C. F. Hanington journeyed through Uruguay, Argentina, Paraguay, and the extreme southern portion of Brazil.

Most colorful of all these tours for Edison, was that of Frank McGowan in the wilds of Peru, Ecuador, and Colombia. At one period, McGowan did not remove his clothes for ninety-eight days. His path was through country made dangerous by wild beasts, venomous snakes, and hostile tribesmen, with swarms of insects a constant

annoyance. He encountered floods, was deserted by his native guides, and twice was stricken with fever. For about fifteen months he was in the wilderness. An editorial in the "Evening Sun" (New York) declared: "As a sample story of adventure, Mr. McGowan's narrative [36] is a marvel fit to be classed with the historic journeyings of the greatest travellers." Strangely enough, having survived the hardships and perils of the jungle and returned to the United States, he vanished so completely as to leave not the slightest trace. He dined with friends at a New York restaurant, entertained them with anecdotes of his wanderings, bade them good-night at the door—and from that moment nothing further was ever seen or heard of him.

Yet another who joined in the fiber-hunt was James Ricalton, a school-principal of Maplewood, New Jersey, and an experienced traveller. He went by way of England and the Suez Canal to Ceylon; thence to India, where he ransacked river-bottoms and tablelands; on to Burma and other parts of the Malay Peninsula; homeward through China and Japan. In exactly one year from the time when he had said farewell to his pupils on the platform of the railway station at Maplewood, he was greeted by them there, having "put a girdle round the earth." Ricalton did, indeed, discover a fiber that (so he states) tested "one to two hundred per cent. better than that in use at the lamp factory." This was from the so-called giant bamboo, which he found growing in both Ceylon and Burma, with a height of as much as a hundred and fifty feet and frequently a diameter of a foot.[37] In the meantime, however, Edison had been

[36] As given in an interview in the same issue, that of May 2, 1889.

[37] Ricalton's own narrative may be found in the Dicksons' "The Life and Inventions of Thomas Alva Edison" (New York, 1894), pp. 212–

developing an artificial filament—a "squirted" filament, as it was termed. A soluble cellulose was prepared and then forced through a die, the result being a long thread that when hardened looked somewhat like catgut. The thread was cut into lengths and these could be formed into desired shapes. After this material was carbonized at a high temperature (the higher the better), the carbon residue was found to be both extremely dense and highly elastic. Gradually the new process was adopted for the commercial production of lamps.

With the bamboo filament, however, Edison's incandescent lamp was established and won its early triumphs; with the bamboo-filament lamp, Edison's electric-lighting system was introduced. During about nine years the Japanese farmer's bamboo fiber, constantly bettered, went to the making of a really serviceable new light-giver, for whose burner nothing else was used. Indeed, well into the 'nineties bamboo was employed for many lamps; and so late as 1908 for certain particular designs.

Upon Edison's fundamental work on the incandescent lamp, the lamp's further development by others was largely based. The cellulose filament was improved by the research laboratory of the General Electric company in what was known as the Gem (*G*eneral *E*lectric *M*etallized) lamp. The carbonizing of the Gem filament was done at temperatures higher than ever previously used; so-called metallized filament, of decidedly increased re-

266; and repeated in D. and M., I, 307–315. In a letter to the present writer, Ricalton said, "While I made a trip around the world in search for fibre for him [Edison], I had only occasionally any personal association with him." . . . In welcoming Ricalton, Edison "extended his hand and said: 'Did you get it?'" Ricalton was at one time employed by Underwood and Underwood (New York) in making, in various parts of the world, scenic photographic views that many readers of these lines have doubtless gazed upon as adapted to the once-popular stereoscope.

sistance, was thus obtained. Hence the lamp could be run at a temperature not possible up to that time. The term "metallized" was applied because this filament behaved more nearly like a filament of refractory metal and less like an ordinary carbon one, which at points of high resistance and high temperature tended to volatilize (*i. e.*, the carbon tended to scatter), with the combined results that the filament speedily broke down and on the inside of the bulb a carbon deposit was formed that blackened the glass and reduced the lighting efficiency of the lamp.

Next, a return was made to refractory metals. Tantalum, drawn into fine wire, was used, but with only moderate success. Its melting-point was high but its resistance relatively so low that quite an amount of filament was needed for a tantalum lamp, and therefore the manufacture of the lamp involved extra difficulties. A tantalum lamp could be recognized by the zigzag pattern of the filament, which was stretched from metal supports held by a glass frame.

Tantalum was supplanted by tungsten, from which filaments were made by the "squirted" process. At first, the brittleness of the tungsten filament made it exceedingly fragile; but by persistent experimenting this drawback was overcome, and it was learned that after suitable preliminary treatment tungsten could be drawn into wire of extreme fineness and great tensile strength.[38] Tungsten-filament lamps in all sizes then came into practically

[38] "William D. Coolidge, of Schenectady, has thus far missed the praise he deserves. When he began experiments, tungsten was so brittle as to be almost worthless for lamp-filaments. He succeeded in giving the metal perfect ductility, and that moment he trebled the efficiency of electric lighting."—Letter of George Iles to the author. Coolidge, a member of the research staff of the General Electric company, in 1914 received the Rumford medal for his services in connection with tungsten.

universal use. For some of these lamps (*e. g.*, those used in street lighting), the idea originally advanced by Sawyer and Man was again taken up and the bulb was filled with argon, nitrogen, or other inert gas.[39]

Then there were the Nernst lamp, employing a filament of magnesia, which when heated by means of radiation from a coil of platinum placed near it, became incandescent; and the helion-filament lamp, in which a carbon filament was covered with silicon. The Nernst lamp had a higher luminous efficiency than carbon-filament lamps had, but was more complicated and could not be produced in units of small candle power. Its burner did not require a bulb exhausted of air but was inclosed in an opal globe.

William J. Hammer, an authority on the history of incandescent electric lamp-making, assembled a collection of lamps representing the development of the art from its earliest days to 1913. This unique and instructive collection, for which Hammer received the Elliott Cresson gold medal from the Franklin Institute, is a permanent exhibit at the headquarters of the American Institute of Electrical Engineers, in the United Engineering Society's building, New York. By 1924, incandescent-lamp technique had produced at one end of the scale a bulb no bigger than a rice-grain, at the other a bulb with a maximum diameter of fifteen inches and a candlepower of 150,000.[40]

Nearly thirty-six full years after that cotton-thread filament shone at Menlo, Edison, stressing the need and importance of constant experimenting, said:

"No invention is perfect, and the incandescent lamp

39 According to census figures, 154,971,000 tungsten lamps were made in the United States in 1921.

40 See the "New York Times" for January 25, 1924.

of today is not an exception. Light without heat is the ideal, and that is still far off. The electric incandescent lamp of today is the cheapest form of filament that has ever been produced, but some day it will be cheaper and colder than it is. There is a good deal of truth in the saying that the firefly is the ideal. It is, so far as coldness goes. But its color is against it. You couldn't use a thousand-candle firefly to match colors, and you wouldn't want the insect to light up a street, because his light would be a hideous greenish-yellow. But some day we will get reasonably near the firefly for efficiency without copying his disagreeable color. The task needs much investigation, much research of the kind we did in 1879."[41]

[41] "Electrical Review and Western Electrician," October 9, 1915; p. 678.

XI

THE "EDISON SYSTEM" INTRODUCED

A SUITABLE lamp was, indeed, the determining factor in Edison's electric-lighting system, as it was in any. Before the system could be realized, however, much else was required. Generators of the right sort had to be designed and built; a scheme had to be worked out whereby current could be satisfactorily distributed to customers; measuring instruments must be contrived that would keep trustworthy records of the current each customer used; and along the various stages of the path from current-source to filament important details of equipment must be provided. Outside of the boilers and steam-engines for driving the generators, Edison had literally to originate every component part. "A still popular misconception of his real work," wrote T. C. Martin, "stops at the lamp, which is about as near the truth as would be an assertion that the Welsbach burner is the whole of gas lighting. Edison really invented a new art." . . .[1]

As for dynamo-electric machines, only those used for arc-lighting were in existence; and for Edison's purpose they would not do at all. Far too little of their motive power was actually utilized in effecting light. Not more than forty-one per cent. of the work done by the Gramme machine was available in the arc; and the Gramme machine was pronounced the most economical of the lot. In other words, more than half of the electrical energy

[1] "Forty Years of Edison Service," p. 5.

produced never managed to get outside the generator that produced it and the conductor that conveyed it. Edison couldn't believe that this was right. A goodly number of the experts of those days thought that in order to get the best results from a dynamo, the internal resistance (or that of the machine) should be as great as the external resistance (or that of the circuit). Edison was convinced that although this might serve for a primary battery, it wasn't the grade of efficiency that might rightly be expected of a dynamo properly built. Further, there was the more strictly commercial side: "He said he wanted to sell the energy outside of the station and not waste it in the dynamo and conductors, where it brought no profits." [2]

When it became known that Edison really was figuring on a dynamo that in economy and efficiency should overtop the standards of the time, he was scoffed at, stormed at, and lectured—very much as he had been for his temerity in fancying he could subdivide the electric current. To-day this seems not a little curious. One must, however, bear in mind that Edison's critics and opponents were so positive mainly because they were so ignorant. No thoroughgoing study, either mathematical or empirical, had then been devoted to dynamo problems. Edison, partly through the knowledge that as a telegrapher he had gained of magnetism and the action of currents, partly through underived reasoning, set the whole scheme of dynamo-building on a new track. Dr. John Hopkinson and others were later to put the subject through mathematical analysis and unfold its theory; but in those days at Menlo, Upton, compiling tables, plotting curves, and making drawings, had not the benefit of such guidance. The few textbooks were hazy and incomplete.

[2] Jehl as quoted in D. and M., p. 292.

Even a terminology was lacking. Upton testifies: "I remember distinctly when Mr. Edison gave me the problem of placing a motor in circuit in multiple arc with a fixed resistance; and I had to work out the problem entirely, as I could find no prior solution. There was nothing I could find bearing upon the counter electromotive force of the armature on the work given out by the armature." [3]

Edison set about improving the contemporary dynamo, and he did improve it. From the summer of 1879, some of this work was going on simultaneously with that upon the incandescent lamp. One of the first things he did was to study armature-cores. Armature-cores were at that time solid. Foucault (or "eddy") currents were developed in them. These currents produced heating that resulted in marked losses. Edison tried sheet-iron cylinders with concentric windings of iron wire; also rolls of insulated iron wire, no cylinder being used. Then he divided the solid iron core into thin layers, with paper between them. This laminated structure very largely did away with eddy currents and the consequent losses from heating. Edison likewise split up the commutator into sections and insulated these with mica, which it is said he was the first to use for this purpose.[4] The amount of iron in the magnets, he greatly increased; and in that respect one of the most conspicuous differences between the Edison machine and its predecessors was to be noted. The yoke of the Edison magnets was in those days considered quite tremendous.

Other matters specially entered into were a comparison of the magnetic features of various sorts of iron; study to determine the approximate saturation-point of the field—that is, the maximum intensity of magnetization of which

[3] D. and M., I, 296.
[4] Jehl as quoted in D. and M., I, 295.

the magnets were capable (an important item to know, that current might not be wasted); and the winding of armature-cores. Jehl and others experimented with dummy armatures of wood, on which they wound twine instead of wire—the process being expedited by wagers as to who first would get the job done. On the basis of what was determined with the dummies, Upton calculated the windings of the sure-enough armatures. It does not appear that this work of Upton's was ever published; but the practical effect of it was far-reaching. After Kruesi had completed the first practical Edison machine in the Menlo shop, and the machine had been tested, it looked as if the gain in economy and efficiency were rather startling. So Upton repeatedly checked over the apparent results. There was no mistake: this dynamo was nothing less than 90 per cent. efficient.

If this was surprising to Upton and gratifying to Edison, to many it was ridiculous. They said so. Upton had the effrontery to make a public statement of the Edison claims.[5] Dynamo manufacturers and other critics, amateur and professional, leaped into print. From that time onward, a new duty fell to the lot of the busy Upton—that of replying and instructing.

Then there was the question of how to drive this remarkable new generator. Dynamos had commonly been driven with belts. In 1880 Edison installed at Menlo a demonstration outfit of ten eight-horsepower dynamos, each driven by a slow-speed steam engine through an intricate arrangement of countershafts. Considerable waste was involved, and waste always bothered Edison. He made plans to replace the ten small dynamos by one large machine, the low-speed engine by an engine of high-speed type, and the countershafts by direct coupling.

[5] "Scientific American," October 18, 1879.

This outfit was completed early in 1881, but it was soon discovered that the engine speed was higher than either economy or safety would warrant. The general idea—that of large, direct-connected units—was right, as was not long afterward established.

Out of a series of varied experiments, the Edison electrolytic (or chemical) meter was evolved.[6] The principle of this meter was simple. In a glass cell two zinc plates were held in a solution of zinc sulphate. A certain definite proportion of current was turned aside to flow through this cell from the anode to the cathode plate, and by electrolytic action, within a given time, a precise amount of zinc would be taken from the one and deposited on the other. Thus the one would lose in weight exactly what the other gained, and the difference would be a pretty accurate index of the current used for any given period on the circuit in which the meter was placed. The cell was removed (another being left in its stead) to a meter-room, where the two plates were washed, dried, and weighed in a chemical balance, and on the basis of the ascertained weight the service-charge was reckoned. The Edison meter worked well and was widely adopted in this country and abroad. Owing, however, to the fact that the zinc-sulphate solution would freeze, the meter had to include an incandescent lamp and a thermostat by means of which as the temperature fell or rose the lamp could be cut into the circuit or out. When the temperature dropped to 40 degrees F. or below, the office-telephone bell would incessantly prelude such messages as "Our meter's red-hot. Is that all right?"—or "Our meter's on

[6] Monthly charges for arc lighting had been arrived at on a loose and crude flat-rate basis—a lamp was supposed to burn a specified number of light-hours for a certain number of nights. Deduction was made for time during which a lamp was out of service.

fire inside and we poured water on it. Did that hurt it?" Of even more consequence from the customer's viewpoint was the fact that readings of the meter could be taken by the service-company only, without possibility of check. In time, therefore, the electrolytic type was replaced by the mechanical type, developed by Elihu Thomson and other workers and generally familiar in the watt-hour meter of to-day.[7]

There was, too, the matter of fixtures. At Menlo were simply the lamps "strung on wires" that Connery pooh-poohed,[8] or (as in Edison's own house) a pair of flexible conductors wound with tape and dangling from a fastening on the ceiling. When first the incandescent lamp was introduced beyond Menlo's borders, the common method was to wind the wires round the gas chandeliers and attach the lamp-sockets to small brackets hitched to the jet. Until Stieringer devised the insulating joint for keeping the gas and electric systems apart, thunderstorms would cause a lively exhibition of sparks between wires and chandelier. It was likewise Stieringer who brought into use the canopy-block (or ceiling-block), to which the outlet-box was attached when special electric-lighting fixtures (or "electroliers") were later made. Before such fixtures came into vogue, the "combination" fixture, for both electric and gas service, was the prevailing thing; it being thought expedient to have gas available in case of an interruption in the supply of current.[9]

All along the line, it was the same: conduits, switches, fuses, connections, service-boxes, lamp-sockets—these and

[7] On p. 68 of "Forty Years of Edison Service" is an excellent half-tone picture from a photograph of one of these obsolete meters.

[8] Chap. X, p. 129.

[9] See "Forty Years," pp. 68–69; D. and M., I, 438.

other devices "too numerous to mention," as auction-bills phrase it, had all to be designed, constructed, and made to function as parts of the new system. This system, as broadly outlined in Edison's application for a patent, was for "multiple distribution from a number of generators through a metallic circuit." The application was signed on January 28th, 1880, but it was not until more than seven years later—on August 30th, 1887—that the basic patent (369,280) was issued by the United States Patent Office. Meanwhile, no end of water had passed under the bridge.

By about the beginning of 1880, the laboratory staff at Menlo comprised "at least one hundred earnest men." [10] That year is described as "extraordinarily busy" for Edison and for "his whole force, which from time to time was increased in number." [11] During the year, Edison applied for sixty patents—five relating to auxiliary parts, six to dynamos, thirty-two to incandescent lamps, seven to distributing systems—one of these last being the basic patent already referred to, another being for his "feeder-and-main" method of preventing, in the words of the application, "what is ordinarily known as a 'drop' in those portions of the incandescent-lighting system the more remote from the central station." . . . It had been found that whereas the two lamps or groups of lamps nearest the current-source burned at their indicated candle power, yet beyond that point a progressive loss in candle power was to be noted—so much so that the last lamp or group of lamps burned at only approximately two-thirds the candle power of the first two lamps or groups. This was because of the resistance inherent

[10] D. and M., I, 324.
[11] *Ib.*, I, 340.

in the copper conductors. The resistance transformed part of the initial voltage (or electrical pressure) into heat; and heat, although of use in the lamp, in the conductors was absolute waste. By the feeder-and-main method, the main conductors (or "mains") had no connection with the current-source. Other conductors, the "feeders," *were* connected with the current-source. They were called "feeders" because through them the current was fed into the mains, to which they were connected at central points. A drop occurred, to be sure, but it was limited to the feeders and did not affect the lamps; the feeders being so arranged as to deliver current to the mains at a potential (or electromotive force) corresponding to the average voltage of the individual lamps, and the extreme loss of voltage in the mains being so small as to make no appreciable difference.

When extensive distribution in a large town is considered, it will readily be seen that by the feeder-and-main method the saving in copper for wires was very decided, for the mains did not have to be run to the central station but only along a given block; and the feeders were of relatively small size. In order to avoid a drop, a conductor eight times as large would otherwise have been required. Any large economy in copper was important if incandescent lighting was to compete with gas. Lord Kelvin (Sir William Thomson), the distinguished physicist, asked why the feeder-and-main method, essentially so simple, had not previously been hit upon by somebody else, replied, "The only answer I can think of is that no one else was Edison." Though in another field, it was something like the case of Edison's process for making duplicates of an original phonograph record. A judge of a Federal court proclaimed this process to be "obvious

to any one"—hence devoid of true invention and therefore not patentable!

Gradually during 1880 Edison's plans for central-station lighting—a commonplace now but then without precedent—had been crystallizing. While the means was being patiently developed at Menlo, the end—that of installing a commercial system and testing it out under actual everyday conditions of demand and supply—was steadily held in view. Edison had always fancied New York as the *locale* of this initial enterprise in public utility. In 1880 the Edison Electric Illuminating company of New York was incorporated. This company was a licensee of the Edison Electric Light company (the original syndicate) and paid for the license partly in cash, partly in shares of capital stock. Such was the regular business arrangement with all the local distributing companies operating under the Edison system. The Edison Electric Light company on its part granted to the licensee exclusive use of the system in a given territory—this being held to include any isolated plants installed within the area specified.

The first president of the New York company was Norvin Green, afterward president of the Western Union Telegraph company. The New York company filed an application for a franchise. Their Honors the Board of Aldermen were not at first persuaded. As Pope's "Odyssey" observes,[12] "How prone to doubt, how cautious are the wise!" Thereupon a special train was provided for them and they were taken out to Menlo. At Menlo and nowhere else in the world a real multiple-arc distributing system was to be seen in operation not only for incandescent lighting but also for power. Edison realized that distributed current was likely to have extensive use in

[12] xiii, 375.

driving motors, and so motors were on circuit in this first system.[13]

The system carried about 425 incandescent lamps. The underground conductors were in tubes, with asphaltum around the tubes to insulate them and with a wood sheathing around the asphaltum. On the occasion of the aldermen's visit, everything went well. The lights were brilliant, for the voltage had been raised a bit; and Edison in person explained the more important features. An informal banquet followed in the laboratory and Edison, rarely a public speaker, signalized the affair by making an after-dinner address.

Other visitors there were, not less distinguished than the aldermen. For example, to Menlo came Lieut. George W. DeLong, leader of the "Jeannette" expedition, of which Bennett of the "Herald" was financial backer. DeLong, then outfitting the "Jeannette," told Edison of the plans for the trip; and Edison promised him a specially-built dynamo—the first for marine use—with a lighting equipment consisting of an arc lamp and a few incandescent lamps. Since the ship did not have a steam-engine available for driving the dynamo, Edison made the

[13] "The motors which to-day furnish power from currents on a large commercial scale are little else than dynamos reversed, yet the reversal, obvious as it seems now, was not adopted until 1873, although it was known to Jacobi in 1850, and probably to Lenz twelve years before. In 1873 several Gramme dynamos were to be shown at the Vienna Exposition. A workman, seeing a pair of loose wires near one of the machines, connected them with it; the other ends of the wires proved to be bound to a dynamo in full rotation, its source of power being a steam-engine near by. The second and newly attached machine at once began to revolve in a reverse direction—as a motor. Thus, in all likelihood by sheer accident, it was discovered that one dynamo may yield in mechanical power the electric energy sent to it from another dynamo at a distance. In the whole realm of industrial art there is no more striking example than this of a rule that works both ways."—Iles, "Flame, Electricity and the Camera," p. 108.

little machine so that it could be operated by hand and, as he said, "keep the boys warm." [14] On the paper insulation put between the iron layers of the armature-core, the members of the Menlo laboratory staff wrote their names. Ship and "boys" were lost in the Arctic, and with them the first incandescent-lighting outfit that ever entered the polar regions.

Sarah Bernhardt came. "One evening"—this is Edison's version—"Robert L. Cutting, of New York [a director of the New York company], brought her out to see the light. She was a terrific 'rubberneck.' She jumped all over the machinery, and I had one man especially to guard her dress. She wanted to know everything. She would speak in French, and Cutting would translate into English. She stayed there about an hour and a half. Bernhardt gave me two pictures, painted by herself, which she sent me from Paris." [15]

From Bernhardt's account [16] we learn that she went to Menlo by special train, arriving at two in the morning of December 5th, 1880, and leaving at four to return to New York. As she was being driven from the station to the laboratory, the outdoor lamps "strung on wires" glittered suddenly in the winter darkness, and great were her astonishment and delight. She found Edison "simple" and "charming," with a manner of "timid graciousness and perfect courtesy" and a "profound love of Shakespeare." "I looked," declares Sarah, "at this

[14] For an importer in the China trade he later made a similar one to be sent to China, where steam-power was more costly than man-power.

[15] D. and M., II, 743. Bernhardt made her first New York appearance on November 8, 1880, and visited Menlo before she left for Boston. She was said to be Edison's choice as "the greatest of women" (see the editorial "Edison at Seventy-Five" in "The World" of February 13, 1922).

[16] "Memories of My Life" (New York, 1907), pp. 392–396.

man of medium size, with rather a large head, and I thought of Napoleon I. There is certainly a great physical resemblance between these two men, and I am sure that one compartment of their brain would be found to be identical. Of course I do not compare their genius. The one was 'destructive' and the other 'creative.'" . . .

The preparative year of 1880 went by, with all-and-sundry "on their toes," improving and re-improving endless items. Edison alone found time for avocations. In looking over the list of patent-applications executed during the twelvemonth, one runs across the entry: "Preserving Fruit, Dec. 11"! Early in 1881, offices of the Edison Electric Light company were opened in the fine old David W. Bishop mansion at 65 Fifth avenue—on the east side of the avenue, just below 14th street. These headquarters were always referred to by Edison associates as "Sixty-five." Here were an isolated generating plant; offices for Edison and for Major Eaton, who had succeeded Norvin Green as president of the company; a reception-room; in the top story, a library. The house had been selected primarily because at this stage of proceedings it was necessary to demonstrate the quality of incandescent lighting for interiors, and "Sixty-five," with its spaciousness and dignity, conveyed the desired effect.

For many months, throngs filled the public rooms by night, the place remaining open until eleven or twelve o'clock. During four years or more, indeed, this continued to be a much-frequented spot.[17] Edison, though for a while compelled to spend considerable time here, seems hardly to have felt at home. He much preferred the comparative seclusion of the laboratory at Menlo. He did not like the general air of being on parade. But at this juncture he was needed to direct the educational

[17] See Meadowcroft, p. 213.

campaign that was heralding the new light. One has glimpses of him—an absorbed figure, grown a trifle stouter; draped (as a slight concession to the heavy convention of the period) in a well-worn frock-coat, the gravity of which was somewhat impaired by a silk handkerchief knotted about his neck in place of a collar; an unruly lock of thick hair drooped across his brow; his headgear a broad-brimmed covering of soft felt. He was only thirty-four; and, smooth-shaven amid the luxuriantly bewhiskered faces that were then the mode, looked scarcely that.

Hours were long, but there were compensations; for after the last sightseer had gone, friends would drop in for a chat in the library and one of them, Eduard Reményi, the distinguished Hungarian violinist, would play his violin—sometimes "$2,000 worth" as Edison calculated, with a slant at the American bent for applying to everything the appraisals of trade. Nor was humor lacking. ". . . I was telling a gentleman one day," Edison alleged, "that I could not keep a cigar. Even if I locked them up in my desk they [his associates at 'Sixty-five'] would break it open. He suggested to me that he had a friend over on Eighth Avenue who made a superior grade of cigars, and who would show them a trick. He said he would have some of them made up with hair and old paper, and I could put them in without a word and see the result. I thought no more about the matter. He came in two or three months after, and said: 'How did that cigar business work?' I didn't remember anything about it. On coming to investigate, it appeared that the box of cigars had been delivered and had been put in my desk, and I had smoked them all!" . . .

The Edison Electric Illuminating company of New York was capitalized at $1,000,000—and small enough

the amount is likely to appear to those familiar with the grandiose "promotions" of these later days. None of this capital could be used for manufacturing. The Edison Electric Light company, so far as it was concerned, was not inclined to go in for any manufacture; hence Edison "dipped deeply into his own resources." "'If there are no factories,' he said, 'to make my inventions, I will build the factories myself. Since capital is timid, I will raise and supply it.'"[18] . . . In addition to what he could get from other quarters, he finally, when it became necessary to finance the works he had established, raised further cash by the sale of his holdings in the Edison Electric Light company. The upshot was but another variation of an old story. After Edison had by personal effort and sacrifice brought his manufacturing interests to the point where they were of high commercial value, financiers, no longer "timid," thought it quite worth their while to engineer the merging of them into the Edison General Electric company, with a capital of $12,000,000 on the basis of an eight per cent. dividend. Pressed for funds to manage an ever-increasing volume of business, Edison thought it best to sell out. That was in 1889.

On March 2nd, 1881, he took over from the veteran shipbuilder John Roach the idle Ætna Iron works plant on Goerck street in an "East Side" region of decayed tenements and other tumble-down buildings. For several years he ran this plant as the Edison Machine works, his first manufactory of dynamos. Gradually, however, it became totally inadequate, and the works were removed to a new plant at Schenectady. Meters, chandeliers, switches, sockets, "and such small deer" were made by

[18] From a statement by Major Eaton (quoted in D. and M., II, 719).

Sigmund Bergmann—first at a shop in Wooster street, afterward in a large manufactory on east Seventeenth street at Avenue B. Bergmann, who had been a bench-worker for Edison in Newark and had later built phonographs in the Wooster-street shop, became a partner in this manufacturing enterprise and eventually chief owner of electrical works in Berlin. When the Edison Illuminating company had obtained its franchise and permit to open the streets, the underground-tube conductors and junction-boxes were made by the Electric Tube company at 65 Washington street, where John Kruesi (the Menlo machine-shop having been closed) was in charge.

The lamp-factory was taken from Menlo to Harrison, New Jersey, near Newark, and there housed in a big structure originally used in the making of oiled-cloth. The stock of the Harrison works was divided into a hundred shares at par $100, some of which were distributed among Edison's assistants. "One of the boys was hard up after a time," said Edison, "and sold two shares to Bob Cutting. Up to that time we had never paid anything; but we got around to the point where the board declared a dividend every Saturday night. We had never declared a dividend when Cutting bought his shares, and after getting his dividends for three weeks in succession, he called up on the telephone and wanted to know what kind of a concern this was that paid a weekly dividend." [19] There were also the short-lived Thomas A. Edison Construction Department (known to Edison men as the "*De*struction Department"), formed to "boom" and install central-station plants at a time when the central-station idea seemed to be hanging fire for lack of financial support; and the Edison company for Isolated Lighting, which installed independent-generating

[19] Meadowcroft, pp. 215–216; D. and M., I, 358–359.

sets at points remote from central-station supply. At "Sixty-five" a night school was maintained for the instruction of artisans in the practice, both electrical and mechanical, of the incandescent-lighting art.

During that year of 1881, while the Edison system was being explained and ushered in, Captain Burnaby by crossing the English Channel in a balloon amazed folk quite as much as did the "air Magellans" of 1924 who, in a hundred and seventy-five days, first sailed around the world in heavier-than-air flying-ships. In that year of grace, Gladstone introduced his Irish land bill; "Tom" Platt and Conkling—he of the "little curl"—resigned in a huff their seats in the Senate (who now remembers why?); the "Jeannette" was crushed in northern ice; the slaves in Egypt were set free; the "Great Eastern" was sold for $150,000; all summer long, the wounded Garfield fought with death. In that year, those benevolent and disinterested spirits Fernando Wood and "Honest John" Kelly passed from the scene of their earthly labors. Cody's "Wild West" had not yet been launched, nor the Brooklyn Bridge opened. An international electrical exposition, first display of its kind, was held in Paris, greatly to the benefit of the whole electrical industry. Thither Edison sent an exhibit of his lighting inventions, for which he received a diploma and was made an officer of the Legion of Honor.

The center of this exhibit was a direct-connected dynamo, the largest he or any one else had yet built. This dynamo, colossal for the year 1881, weighed twenty-seven tons (including the engine and a six-ton armature) and would serve to light from 1,000 to 1,200 standard lamps. It was started for a test run at the Goerck street works on June 25th and ran until five o'clock the next morning, when the engine crank-shaft snapped, flying

"clear across the shop." A new shaft was attached and a second test was satisfactorily run. Only about four hours remained in which to get the dynamo to the "French Line" pier. A gang of sixty men, each with his particular instructions, took down the machine and loaded it on waiting trucks. Then through specially-policed streets dashed the horses, preceded by a clanging bell; and with but an hour to spare, the dynamo was got aboard. When set up and running at the exposition, it was admiringly studied by foreign electricians, and was a factor in the introduction of the Edison system on the Continent. It was the first example of what was styled the "Jumbo" type—so called from Barnum and Bailey's big elephant, which P. T. Barnum's publicity methods made so well known that its name passed into English speech and found place in the dictionaries.

With the exception of the little experimental station at Menlo Park, the world's first central station for incandescent lighting was that installed in London by the English Edison Electric Light company, of which E. H. Johnson was general manager and W. J. Hammer chief engineer. On January 12th, 1882, Hammer closed the switch by which the plant was put into service. The station was on Crown land on Holborn Viaduct and its three thirty-ton "Jumbos" supplied 3,000 lamps in that neighborhood [20]—including four hundred in the telegraph operating-room of the General Post Office at St. Martin's-le-Grand.[21] Hammer says that Johnson "was kept busy

20 Information kindly supplied by W. J. Hammer.

21 As already stated in a foot-note to Chapter VIII (p. 80), the British telegraphs were taken over by the government in 1870. Telegraph service was put under the direction of the postal authorities. These lamps in the General Post Office were placed at the instance of W. H. (Sir William) Preece, who had ceased to regard the light as

not only with the cares and responsibilities of this pioneer English plant, but by negotiations as to company formations, hearings before Parliamentary committees, and particularly by distinguished visitors, including all the foremost scientific men in England, and a great many well-known members of the peerage." [22]

From MS. notes by Johnson, T. C. Martin quotes as follows:

"At this time tall masts surmounted by a group of high candle power arc lamps were much in vogue in London, and I desired to enter into competition with them by substituting an electric lamp of 32 candle power for the ordinary gas jet on each gas post throughout the length of the Holborn Viaduct. For this permission was granted me by the city, and the work was carried out eliciting an extremely favorable criticism from the press and public generally. This was unquestionably the beginning of the end of group arc lighting, and I think may now be taken as the beginning of the end of the arc light itself." [23]

Had it not been for the British electric-lighting act that provided that at the end of a twenty-year interval electric-light plants were to be taken over by the government, the Holborn Viaduct station would, one may suppose, have become the basis of a great metropolitan system and the prototype of other such stations throughout the British Isles. The act was later repealed. But just as the early development of the horseless vehicle in England had been impeded by legislation affecting the use of steam carriages on highways, so now the incandescent-

an *ignis fatuus* and was now among its most outspoken supporters in England.

[22] D. and M., I, 337–338.

[23] "Forty Years," p. 29.

lighting industry received a set-back. The station was dismantled, the service given up; but not until Hammer and Johnson had accomplished much of interest and learned much that was later useful.

The next central station, the first in the United States, was the Pearl street station in New York. To the work connected with planning and installing the entire plant, Edison devoted a large amount of direct personal attention. The station was in a double building at 255–257 Pearl street, four stories high, on a lot measuring 50 × 100.[24] Of the two parts, 257 was converted into the generating plant, 255 was used for storage, repair-shops, and a factory in which were made the tubes for the underground distribution system. Over fifteen miles—more than 80,000 linear feet—of these tubing conductors were needed for the district that Edison had selected and mapped. This First district had an area of about a square mile in a region sometimes called "The Swamp." It was bounded on the north by Spruce and Ferry streets and Peck Slip; on the east by the East river; on the south by Wall street; on the west by Nassau street.

Edison had originally planned a district of much greater area, reaching from Wall street on the south to Canal street on the north, and from the East river to Broadway. Before long, however, he decided that this was altogether too much ground to cover. In the meantime he had conducted a preliminary survey of the whole tract with a view to learning the number of gas jets in each building, how much gas on the average was daily used throughout the district and by each customer; how

[24] D. and M., I, 394. *Cf.* ". . . I could only get two buildings each 25 feet front, one 100 feet deep and the other 85 feet deep." (From Edison's notes furnished to T. C. Martin and quoted by Martin in "Forty Years," p. 34.)

much power was demanded and by whom; where hoistways and elevator-shafts were in which electric power could be made available. After the invention of the feeder-and-main method,[25] large-scale maps were prepared showing every last detail necessary for installing the system.

Pearl street (the name of which harks back, it is said, to the wampum currency employed in trading with the Indians) is a thoroughfare marked by notable beginnings. Some have said it was the first street to be occupied when white men settled on Manhattan island. On it, at any rate, the first stadt-huys (or city hall) of New Amsterdam was built; on it was the structure in which William Bradford set up the colony's first printing-press. When the nineteenth century was younger, here were abodes of the wealthy, the fashionable, the socially ambitious. What says Halleck in "Fanny?"

> "Her father kept, some fifteen years ago,
> A retail dry-goods shop in Chatham street,
> And nursed his little earnings, sure though slow,
> Till, having mustered wherewithal to meet
> The gaze of the great world, he breathed the air
> Of Pearl street, and set up in Hanover Square."

But by 1881, Time and Change had so wrought that Edison picked out Pearl as "the worst dilapidated street there was." "I thought," he afterward wrote, "that by going down on a slum street near the waterfront I would get some pretty cheap property." [26] About $20,000, he figured, would take the two buildings. He learned something about New York's highly artificial real-estate prices —even on "the worst dilapidated street." ". . . I found

[25] See a previous reference in this chapter, pp. 148–149.
[26] Notes furnished to Martin. See "Forty Years," p. 34.

that they wanted $75,000 for one and $80,000 for the other." A tentative plan of his had been for a station 200 × 200. Such spaciousness he was compelled to forego. The old flooring of 257 was cleared out and an inner structure of ironwork—stout columns carrying substantial girders—running about three-quarters of the building's depth, was snugly fitted within the walls. Six "Jumbo" dynamos with their direct-coupled Porter engines were located on the second floor.[27]

Laying of mains was begun late in the autumn of 1881, interrupted by frost, and renewed in the spring of 1882. Day and night the work was carried forward; and by day and by night Edison might be found with the ditching gang. A contemporary illustration in "Harper's Weekly" shows him testing tubes for insulation. ". . . I saw every box poured," were his own words, "and every connection made on the whole job."[28] On the third floor of the station a bedroom had been provided for him, but he found another more convenient. In the cellar at Pearl street a stock of tubes was kept. "As I was on all the time, I would take a nap of an hour or so in the daytime —any time—and I used to sleep on those tubes in the cellar."[29] Two men who were employed in testing in that damp, chill cellar, died of diphtheria. "It never affected me" was Edison's comment; his high vital resistance stood him in good stead—and then, as Martin observes, he wasn't in the cellar long enough at any one time. He was his own superintendent of construction and more immune to fatigue than was any of his assistants around the

[27] A detailed account of the chief features of this installation may be found in Martin's "Forty Years," pp. 43–51.

[28] Statement for the "Electrical Review," quoted by Jones, pp. 114–119.

[29] "Forty Years," p. 43; D. and M., I, 400.

station, for whom "a shave and a clean shirt were rare enjoyments."

It has been inferred that no precedent existed for the underground disposal of conductors. This is not quite correct. In 1839 Cooke and Wheatstone, when they ran their thirteen miles of telegraph-line from the Paddington station (London) of the Great Western railway to West Drayton, put inside wrought-iron tubing six copper wires. The tubing was laid by the side of the railway and about six inches from the ground. Morse tried for his Washington-Baltimore telegraph-line (1843–1844) some ten miles of cable drawn through lead pipe. The wires of Cooke and Wheatstone were covered with hemp; Morse's with cotton and shellac. Cooke in 1842 introduced the method of stringing wires from insulating supports placed on poles—with excellent results. Only when his underground cable had completely failed, did Morse, in his struggle to establish his invention commercially in the face of apathy and doubt, resort to Cooke's second scheme. His success led to a long abandonment of underground conductors. It was inevitable that the business heads of public-utility corporations, solicitous for themselves and their stockholders, should consider little else but the lower initial cost of overhead-wire installation. They went ahead with little or no check. They said underground conductors were silly; and practically no more experimenting was done in that field. A brief study of photographs dating from the late 'seventies and early 'eighties, will show that in larger American cities the leading streets had become much disfigured by unsightly poles carrying a medley of interlacing wires. Smaller towns suffered in proportion and the countryside was invaded. Marring every vista into which they were thrust, the wires sagged from rickety cross-arms; or they rotted

apart, and were left dangling. The imperfectly insulated arc-lighting wires did more: they conveyed dangerous high-tension currents. OK'd by the insurance companies and hence known to "the trade" as "underwriters," they were often styled "undertakers"—which, if not supreme wit, at least bears a grim hint of their quality. Chance contacts with adjacent metalwork or with low-tension lines that crossed them, made them a menace. Casualties were altogether too frequent. Hence in many places public sentiment compelled the law to step in and require that wires go underground.

From the very first, Edison had no other intention than to put his mains in the earth. "Why," he would say, "you don't lift water pipes and gas pipes up on stilts." [30] He saw that the underground way not only was the more suitable for conductors so large and weighty as he would use, but also was destined to be the one approved way within the limits of big cities. ". . . When New York State legislation created the underground system for Manhattan Island," Martin points out, "the engineer chosen for the Board of Electrical Control was S. S. Wheeler, who had 'learned how' working side by side with Edison on the mains for the First District fed from old Pearl Street." [31] Yet such is human prejudice that years after Edison had demonstrated the success of his conduits, the question of "underground" *vs.* "overhead" came near to splitting the National Electric Light Association.

Edison not only learned about New York's fantastic prices for real-estate but also had a glimpse of the *modus operandi* of New York's municipal government as it then was. ". . . The office received notice," so he told, "from

[30] Martin, "Forty Years," p. 38.
[31] *Ib.*

the Commissioner of Public Works to appear at his office at a certain hour. I went up there with a gentleman to see the commissioner, H. O. Thompson. On arrival he said to me: 'You are putting down these tubes. The Department of Public Works requires that you should have five inspectors to look after this work, and that their salary shall be $5 per day, payable at the end of each week. Good-morning.' . . . We watched patiently for those inspectors to appear. The only appearance they made was to draw their pay." . . .[32]

The laying of the mains at last was done; and while customers were being "hooked up" to the system and their meters were being installed, there followed a period of rigorous testing at the station. A pair of "Jumbos" proved startlingly fractious. Let Edison tell the story.[33] "Finally we got our feeders all down and started to put on an engine and turn over one of the machines to see how things were. . . . Then we started another engine and threw them in parallel. Of all the circuses since Adam was born we had the worst then. One engine would stop and the other would run up to about a thousand revolutions, and then they would see-saw.[34]

"What was the matter? Why, it was these Porter governors! When the circus commenced the men who were standing around ran out precipitately, and some of them kept running for a block or two. I grabbed the throttle of one engine and E. H. Johnson, who was the only one

[32] D. and M., I, 393.

[33] Statement for the "Electrical Review"—see Jones, pp. 116–117; also "Forty Years," 56–57.

[34] This difficulty with the engines in multiple was termed "hunting." C. L. Clarke, chief engineer of the Edison Electric Light company, thought it due in this case to vertical vibration rendered possible by the fact that the bedplates were not on a solid foundation but on the iron girders already mentioned (p. 162).

present to keep his wits, caught hold of the other and we shut them off. Of course I discovered then that what had happened was that one set was running the other one as a motor. I then put up a long shaft connecting all the governors together, and thought this would certainly cure the trouble, but it didn't. The torsion of the shaft was so great that one governor still managed to get ahead of the others. Then I went to Goerck Street [*i. e.*, to the machine works] and got a piece of shafting and a tube in which it fitted. I twisted the shaft one way and the tube the other as far as I could and pinned them together. In this way, by straining the whole outfit up to its elastic limit in opposite directions, the torsion was practically eliminated, and after that the governors ran together all right."

Apparently he did not, however, trust this makeshift. ". . . I got hold of Gardiner C. Sims, and he undertook to build an engine to run at 350 revolutions and give 175 horse-power. He went back to Providence and set to work and brought the engine back with him. It worked, but only a few minutes, when it busted. That man sat around that shop and slept in it for three weeks until he got his engine right and made it work the way we wanted it to. When he reached this period I gave orders for the works to run night and day until we got enough engines." [35]

On September 4th, 1882, the current was turned on for the regular distribution of light. The hour was three of the afternoon. One can but echo the comment of

[35] For long thereafter an Armington-Sims engine was invariably an integral part of an Edison dynamo installation. Sims said: "The deep interest, financial and moral, and friendly backing I received from Mr. Edison, together with valuable suggestions, enabled me to bring out the engine. . . . Mr. Edison was a leader far ahead of the time." . . . (D. and M., I, 422.)

"The World" (New York) just forty years later: "The skyscraper had not ascended and it is a bit of a question just why the lights were flashed on at 3 o'clock in the afternoon since the effect then could not have been so good as it would be to-day with towering structures aiding the lights by shutting out the sunlight." Many of those identified with the Edison interests were on hand, as were a representative of the Board of Fire Underwriters; Joseph Wetzler of the "Electrical World" and "Scientific American"; and reporters for the local newspaper press. Next day the "World" said: "Most of the principal stores in Fulton Street from Nassau Street to the East River were last evening for the first time lighted by electric light." It is claimed for Edison that he was at first garbed *en règle* for the occasion, with "Prince Albert," collar, and cravat; but apparently at least a portion of this apparel had been cast aside, for the "Sun's" account noted his "white, high-crowned derby and collarless shirt."

Said the "New York Times" of September 5th: ". . . It was not until about 7 o'clock, when it began to grow dark, that the electric light really made itself known and showed how bright and steady it is. Then the 27 electric lamps in the editorial rooms and the 25 lamps in the counting-rooms made those departments as bright as day, but without any unpleasant glare. It was a light that a man could sit down under and write for hours without the consciousness of having any artificial light about him. There was a very slight amount of heat from each lamp, but not nearly as much as from a gas-burner —one-fifteenth as much as from gas, the inventor says. The light was soft, mellow, and grateful to the eye, and it seemed almost like writing by daylight to have a light without a particle of flicker and with scarcely any heat

to make the head ache. The electric lamps . . . were as thoroughly tested last evening as any light could be tested in a single evening, and tested by men who have battered their eyes sufficiently by years of night work to know the good and bad points of a lamp, and the decision was unanimously in favor of the Edison electric lamp as against gas." . . .

The plant, supplying about four hundred lamps, was a demonstrated success, but for about three months no charge was made for service. The lighting of the Drexel building "was considered a real achievement because of its great size. It was equipped with 106 lights."[36] A letter from President S. B. Eaton, printed in the "Sun" of December 3rd, stated: "We are now lighting one hundred and ninety-three buildings, wired for forty-four hundred lamps, of which about two-thirds are in constant use." . . . By the spring of 1884, more than 11,000 lamps were in circuit and the number of "Jumbos" had been increased from six to eleven. Gradually criticism from the die-hards ceased in the face of actual performance. The station continued in use until 1895. From beginning to end, it knew no pause except for a few days in January, 1890, when all but one of the dynamos were wrecked by fire caused by a heavy short-circuit on one of the feeders. The four Babcock and Wilcox boilers were uninjured and afterward did their bit in the Fifty-third street station until 1902.

It was for years invariably asserted that the first commercial Edison station in the United States was that at Appleton, Wisconsin, which, so it was said, was started on August 15th, 1882; and some writers, eager for the glory of Pearl street, hastened to add that Appleton had only one small water-driven dynamo and therefore didn't

[36] "The World," September 4, 1922.

count. When preparations were under way for celebrating (1922) forty years of service in New York, search in newspaper files revealed the fact that contemporary accounts fixed September 30th as the date of Appleton's beginning.[37] It remains true, however, that the Appleton station *was* the first water-power station of the Edison system.

On October 18th, 1917, exercises were held at the electrical exposition in the Grand Central Palace, New York, to dedicate a bronze tablet that later was placed on the building at 257 Pearl street. The tablet was set up under the joint auspices of the American Scenic and Historic Preservation Society and of the New York Edison company, successor to the Edison Illuminating company of New York. The upper third of the tablet is occupied by a bas-relief (taken directly from an illustration in the "Scientific American") showing the dynamo-room of the station; below, is this inscription:

1882 1917
IN A BUILDING ON THIS SITE AN ELECTRIC
PLANT SUPPLYING THE FIRST EDISON
UNDERGROUND CENTRAL STATION SYSTEM
IN THIS COUNTRY AND FORMING THE ORIGIN
OF NEW YORK'S PRESENT ELECTRICAL SYSTEM
BEGAN OPERATION ON SEPT. 4, 1882
ACCORDING TO PLANS CONCEIVED AND
EXECUTED BY
THOMAS ALVA EDISON
TO COMMEMORATE AN EPOCH-MAKING EVENT
THIS TABLET IS ERECTED BY
THE AMERICAN SCENIC AND HISTORIC
PRESERVATION SOCIETY
THE NEW YORK EDISON COMPANY

37 "Forty Years," p. 30.

Other very early stations were that at Sunbury, Pennsylvania, started on July 4th, 1883; that at Brockton, Massachusetts, started on October 1st, 1883; and those at Lawrence, Massachusetts, and at Fall River in the same state, started, respectively, in November and December, 1883. The Brockton plant had underground conductors, for the reason that those who were backing it had wise thought for the town's beautiful shade-trees and were determined to preserve them from the ruthless trimming accompanying overhead wires. It would have been well if more towns had been thus guarded. For some time this plant was considered a "show" installation of the Edison system; and both the first fire-engine house and the first theater to be lit from an incandescent-lighting central station, were in Brockton. The Sunbury plant had pole-line construction, and here was first used the "three-wire system," invented independently and at almost the same time by Edison and Dr. John Hopkinson of England.[38] For direct-current installations of any size, this system is to-day in practically universal use.

This is the general idea of it: There are two generators, each of them turning out current at 110 volts; and when these generators are connected in series, the main circuit has a potential of 220 volts. Now, with this arrangement, two standard 110-volt lamps may be used on each individual lamp circuit; the two together requiring no more current than would be taken by one lamp on the original multiple-arc system. In order, however, that in any series of two lamps the turning out of one may not involve the other (as it would do in a two-wire system), a compensating conductor, known as the "neutral wire," is

[38] Fleming, "Fifty Years of Electricity," p. 226. The Sunbury installation has quite mistakenly been called "the world's first electric light plant." (See the "Herald Tribune" of August 22, 1924.)

employed. This in effect produces a system with two sides (positive and negative) or two main circuits combined in one, the "neutral" serving at once as the outgoing conductor of one circuit and the return conductor of the other. When all lamps are burning on all lamp-circuits, perfect balance exists between the two sides and the third (or central) conductor is truly neutral. But if a lamp on one side or the other be turned out, balance is forthwith destroyed; that is, although no other lamp is affected, there is an excess of current, and that excess flows back *via* the "neutral" to the generator. If the extinguished lamp is on the positive side of the system, the "neutral" becomes the negative of that side; if the lamp is on the negative side of the system, the "neutral" becomes the positive of that side. Three-wire distribution represents a marked economy over any preceding method. The saving in copper is very large, as will be easily appreciated when it is pointed out that the doubling of potential, rendered possible by three-wire mains, permits the two outside wires to be of one-fourth the cross-section demanded by a two-wire system.

Other "firsts" of Edison incandescent-lighting history may have sufficient interest to be noted here:

—The first church to be illuminated was the City Temple, London, of which Dr. Joseph Parker was pastor. This was lit from the Holborn Viaduct station. William J. Hammer, chief engineer, has commented on the pleased surprise expressed by Doctor Parker and others connected with the church as to the improvement in temperature when incandescent lamps took the place of gas-jets (1882).

—The first commercial house to use the new light, was that of Hinds and Ketcham, New York lithographers, for whom an isolated plant was installed in January, 1881.

The firm was thus enabled to do color-printing at night.

—The first electric sign was designed and built by W. J. Hammer for the Crystal Palace Electrical Exposition, London, in 1882. This sign spelled EDISON in electric lights above the organ in the concert-hall. Hammer also built the first automatic motor-driven electric sign, which flashed EDISON letter by letter and as a whole on the Edison pavilion at the Health Exhibition in Berlin in 1883.

—The first electrolier was one placed in F. R. Upton's house at Menlo in 1880.

—The first hotel plant was that started in the Blue Mountain House on Blue Mountain Lake in the Adirondacks in October, 1881. At that time the hotel was about forty miles from the railway. It has also been stated that the first electric lamp used in an elevator was placed in a car at the Blue Mountain House on July 12th, 1882.

—The first newspaper office to employ the light was that of the "Herald," in which had appeared Marshall Fox's article.

—The first theater to abandon gas was the Bijou in Boston. An isolated plant was ready for the opening of this house on December 12th, 1882, when the attraction was the Gilbert and Sullivan opera "Iolanthe."

—The first steam yacht to be equipped (early in 1882) was James Gordon Bennett's "Namouna."

—The first United States Government steamer to carry a plant was the Fish Commission's "Albatross" (1883).

—The first permanent station on the continent of Europe was that opened at Milan, Italy, on March 3rd, 1883.

—The first South American station was that put in operation at Santiago, Chile, in the summer of 1883.

—The first bill collected by the Edison Electric Il-

luminating company of New York was for $50.40 from the Ansonia Brass and Copper company of 17–19 Cliff street, on January 18th, 1883. That lighting companies' bills were by later custom somewhat more promptly rendered, is indicated by this paragraph from the "New York Tribune's" editorial page of February 2nd, 1924: "On January 31 Edison's birthplace was lighted for the first time with electricity, and undoubtedly in the February 1 mail was the first electric light bill."

—The first quarterly dividend of that company was of 1 per cent. and was paid on August 1st, 1885.

It would be an error to suppose that the introduction of incandescent lighting was a whirlwind affair. Far from it. There was an immense public curiosity about the light, as there had been about the phonograph. Its superiorities—for interior use, at any rate—to arc lighting and to gas were reasonably apparent and in due time generally admitted. But it had to contend against several things. First, of course, was mass inertia. In a newspaper interview in 1923,[39] Edison smilingly said (referring not to his lighting system but to his advocacy of turning coal into power at the mines instead of transporting it), ". . . You know it takes from seven to forty years to put an idea over on the public. Even a self-evident proposition requires about ten years." Then there was the natural opposition of the gas and arc lighting industries. ". . . Forty years ago," wrote Martin in 1922,[40] "electric lighting 'systems,' spawning in reckless profusion, were usually based on some minor changes in the arc lamp or the dynamo. . . . The new arc lighting companies cluttered up the stock exchanges with their securities, and the work shops with casual jobs making

39 "The World," October 18.

40 "Forty Years," p. 7.

and repairing their machinery. It was a 'halcyon time' while the boom lasted. At one period, the *Electrical World* carried the advertising of nearly fifty arc lighting 'systems.'" More than that, a large number of local companies had been organized; and in only too many cases where contracts and franchises were sought and given, had arisen those anti-social alliances between selfish business-men and venal politicians that long were viewed with complacence by the majority of American citizens and made American municipal government an international byword.

Now, the incandescent system was to find its true and logical beginnings in central-station distribution in the more thickly populated communities. To this end, local ordinances had to be passed, franchises had to be obtained, and capital had to be interested in the system's possibilities. Thus was aroused a whole brood of animosities, the vigor of which may be indicated by the assertion of Dyer and Martin [41] that when in 1885 the National Electric Light Association was formed, "its organizers were the captains of arc lighting, and not a single Edison company or licensee could be found in its ranks, or dared to solicit membership."

The gas industry was equally resentful—more so, perhaps, if resentment were to be gauged by the amount of capital invested.[42] The arc-lamp had cut into the gasman's open-air service. It had even in some instances supplanted gas for the lighting of indoor areas of uncommon size. This was bad but not so very bad, because it left to the gas-man the entire domain of ordinary interior lighting. Into this domain came the upstart pear-

[41] D. and M., I, 351.

[42] In 1879 the world's gas investment was estimated at $1,500,000,000. (See "Forty Years," p. 11.)

shaped bulb with its frail-looking filament and its irritating friends with their way of pointing out that it didn't produce flicker or flare and didn't require a match. That was too much for the gas-man. Fortunately, it seems never to have occurred to the gas-man to try to get control of incandescent electric lighting; fortunately, because, had this industry been his, one may be almost certain that he would have done his best to side-track or stifle it and thus have delayed yet longer the benefits it offered.

As time passed, a prediction was verified that Edison had jotted down in one of his series of laboratory notebooks. In places where gas plants existed, the use of gas was greatly extended. Gas found domestic employment not in lighting (gas lighting became obsolescent and new installations of it were not made) but for cooking and heating. New devices were developed for it. Total gas consumption was not diminished but increased. In city after city (as in New York, in the case of the Consolidated Gas company) gas and electric interests were united, and the applications of both electricity and gas were set before the public by well-managed methods of educational publicity. Furthermore, such gas lighting as continued to be used was greatly improved as to brilliance and steadiness by the Welsbach burner, the invention of Dr. Auer von Welsbach of Vienna. This burner, which incidentally effected an economy in gas, allowed the gas flame to play upon a mantle of rare earths.

As for arc-lighting in any industrial sense, it "folded its tents like the Arabs." Save for occasional small-town installations, high-power incandescent lamps more and more crowded arc lamps from even the outdoor field. The arc came to have its uses chiefly in apparatus for projecting motion-pictures, and for searchlights in mili-

tary field-units, in coast defenses, and on naval vessels. The ban of the National Electric Light Association was long since lifted and forgotten. Of all those "nearly fifty" arc "systems" of yesteryear, not one remains. The incandescent-lighting companies supply current for arc-lamps.[43] Rivalry has ceased because one of the rivals has "as utterly vanished from the scene as the dinosaur and the dodo." Moreover, the arc-lamp has itself been much modified and thoroughly improved.

On September 4th, 1882, the Edison Electric Illuminating company of New York was lighting about four hundred lamps for a handful of customers. On June 30th, 1922, the New York Edison company (successor) was lighting 9,337,114 incandescent lamps for 313,521 customers—to say nothing of current supplied for arc lamps, motors, heating appliances, storage-battery charging, and so forth.[44] In 1922 no less than 14,000 communities in the United States were being served by central stations and municipal plants having 11,500,000 customers with an average of 32.65 incandescent lamps a customer—making a total of 375,475,000 lamps. These plants also furnished energy for prime movers having a combined horsepower of 23,000,000.[45] (It is perhaps worth adding that the coal consumed to produce electric energy for domestic lighting amounted to but approximately one-third of one per cent. of the country's total annual coal production.) The investment in plant and equipment was valued at $5,100,000,000.

The "Jumbos" of Pearl street, driven by high-speed engines, would each take care of 1,200 Edison standard

[43] On June 30, 1922, the New York Edison company had on circuit 12,882 arc-lamps.

[44] Company's figures, "Forty Years," p. 175.

[45] Figures of the Society for Electrical Development.

16-candlepower lamps—in an emergency, 1,750. This would give, at the maximum, 168,000 candlepower for the six original machines. On May 12th, 1924, the Brooklyn Edison company put into service the first of four 50,000-kilowatt [46] turbo-generators with which its Hudson avenue station (on the East river, between Hudson avenue and the Navy Yard) was to be equipped. It was estimated that each of the units, when operated at full capacity, would light 2,000,000 25-watt lamps or 500,000 100-watt lamps. This would give a total of 50,000,000 watts; and since a tungsten lamp yields from 0.80 to 1.00 candles per watt, would mean from 40,000,000 to 50,000,000 candlepower.[47] The complete installation contemplated an eventual total of eight generators.

All these later figures patently testify to a triumphant growth and will readily enough impress the average American, always likely to be impressed by the mere idea of super-bigness. What the average American perhaps needs to have stressed with respect to these figures and this growth, is the rock out of which they were hewn, the pit out of which they were digged. Referring to the pioneer days of the Edison system, Major Eaton reminiscently declared: "In looking back on those days and scrutinizing them through the years, I am impressed by the greatness, the solitary greatness I may say, of Mr. Edison. We all felt then that we were of importance, and that our contributions of effort and zeal were vital. I can see now, however, that the best of us was nothing

[46] A kilowatt equals 1,000 watts; 50,000 kilowatts would be the equivalent of 67,000 horsepower.

[47] "Year Book, 1923" of the Brooklyn Edison company, pp. 21–22; "The New York Times," May 13, 1924; "The World," same date. The units of this generating plant, like those of other waterside stations, are driven by low-speed steam turbines.

but the fly on the wheel."[48] It was Edison who enunciated the general principles in accordance with which the whole electric central-station industry was to grow. On the art made possible by a very flood of Edison inventions, that industry was soundly based. That the art has undergone numerous modifications, the industry seen many changes of practice, are matters of course when one considers the swift march of electrical science, the aggregate talent continuously devoted to improvement and progress. But the elements remain as Edison left them, both in his lamp and in his scheme of distribution; and those early dynamos, though they have become things of curiosity, exhibits for museums, nevertheless for the first time established certain fundamentals that but live more fully in the great machines of to-day.

On May 6th, 1915, the Civic Forum, New York, presented to Edison its medal for public service. In an address delivered on that occasion,[49] Richard C. Maclaurin of the Massachusetts Institute of Technology said: ". . . You recognize that he laid the foundations for the design of central power stations and that his Pearl Street Station was a landmark in the history of science. . . . The three-wire distribution, the system of feeders entering the network of mains at different points, the underground conductor system, the bus system in stations,[50] the innumerable accessories of switches, fuses, meters, etc., that he provided are each achievements that would make the fame of any individual."

The years 1879–1883 inclusive constituted the great

[48] D. and M., II, 719–720.

[49] The address, "Mr. Edison's Service for Science," may be found in "Science" for June 4, 1915, pp. 813–815.

[50] Bus-bars ("bus" from "omnibus") are devices by which current is led from the generators to the switchboards.

productive period of Edison's career as an inventor, with 1882 the peak year.[51] This lustrum included that whole prodigious group of labors on the incandescent electric lamp and in distributing, regulating, and measuring electric current. Within its limits also fell Edison's experiments (treated of elsewhere in this volume) as a pioneer of electric traction, and his invention of the magnetic ore separator, upon which he was in time to base (as we shall see) a notable adventure in engineering. So filled were these years with laboratory work, so active with the solving of manufacturing problems, so busied with the introduction of the new system, that it was thought necessary to take the chance of letting patent-rights go undefended. Defense, when finally taken up, involved a series of long-contested and costly suits.

Roughly speaking, from 1885 to 1901 the Edison Electric Lighting company, owner of the Edison patents, spent upward of two million dollars in prosecuting more than two hundred lawsuits brought against persons who were infringing upon many of the patent-rights of Edison on the incandescent electric lamp and component parts of his system.[52] "I fought for the lamp for fourteen years," declared Edison, "and when I finally won my rights there were but three years of the allotted seventeen left for my patent to live. Now it has become the property of anybody and everybody." The lamp patent was issued to Edison on January 27th, 1880. Not until October 4th, 1892, or slightly more than twelve years and eight months after the issuance of the patent, did a United

[51] In D. and M., I, 140–141, it is stated that 141 patents were applied for in that year. The list on pp. 952–956 records the execution of 107 applications. Several other inventions were kept as "trade secrets," no patents being sought for them.

[52] D. and M., II, 720–721; Jones, p. 122.

States Circuit Court of Appeals, in a suit against the United States Electric Lighting company, file a decision in which the patent was sustained. Nor did this decision and the subsequent injunctions put an end to the pirates, for infringing companies thereupon asserted the priority, with respect to the lamp, of Henry Goebel, a New York watchmaker who, it was absurdly claimed, had made a practical incandescent lamp previous to 1854![53] In New York a Federal judge sustained the Edison patent, stating in his opinion that on the basis of the evidence "whatever Goebel did must be considered as an abandoned experiment." In St. Louis, however, a Federal judge failed to sustain it. "That adverse decision at St. Louis," once commented Major Eaton, "would never have been made if the court could have seen the men who swore for Goebel."[54] Edison is himself authority for the statement[55] that he "never enjoyed any benefits" from his lamp patents.

The year 1889, in which Edison and his associates sold out their manufacturing interests to the Edison General Electric company, a syndicate headed by Henry Villard, marked virtually the end of what may be called the inventor's incandescent-lighting phase. Villard, in his "Memoirs,"[56] thus tells the story of how the Edison General Electric company was formed:

"Mr. Villard took a strong interest in electric lighting

[53] In much the same way, Daniel Drawbaugh of Eberly's Mills (near Harrisburg), Pennsylvania, claimed that he had anticipated the telephone.

[54] D. and M., II, 733.

[55] *Ib.*, 716.

[56] Chapter viii of this work (2 vols., Boston, 1904) was written by Villard in the third person, and it is from that chapter that these words are quoted (pp. 325-326).

from its earliest stages. He was one of the first stockholders and a director of the original Edison Light Company,[57] which had acquired the patents for the incandescent lamp. His faith in the incalculable value of the invention was, like that of most of his fellow-stockholders, so great that he did not dispose of his holdings even when the shares, on the par value of one hundred dollars of which only thirty per cent. had been paid in, rose to four thousand. In Berlin he had become acquainted with Werner Siemens, the eminent German discoverer and inventor in the electrical field, and head of the great firm of Siemens & Halske, and also with the parties managing and controlling the General Electricity Company of Berlin, which has since grown into the principal electrical manufacturing and contracting company in Germany. He proposed to them and to his syndicate, before his return to New York, that they should join with him and enter the electrical business in the United States by an alliance with existing American interests. . . . He matured a scheme for the absorption of all the Edison Light and Manufacturing Companies into a new corporation, with sufficient fresh capital for manufacturing electrical apparatus on a large scale. Out of this grew the Edison General Electric Company, organized in April, 1889, with a capital of $12,000,000, of which he and the German parties named held over one half. He became president of it and remained such until the summer of 1892." . . .[58]

In 1884 Edison's first wife had died, and in 1886 he

[57] *I. e.*, the Edison Electric Light company.

[58] The company was consolidated with the Brush and Thomson-Houston interests, and Villard, disapproving of this step, retired from the presidency.

had married Miss Mina Miller, daughter of the Lewis Miller already mentioned (Chapter IX) as one of the originators of the "Chautauqua movement." In 1887 he left Menlo Park and established at West Orange, New Jersey, a model laboratory around which, as a center, grew up various manufacturing enterprises of his. Close at hand, in the residential section known as Llewellyn Park, he purchased the three-story mansion "Glenmont," set in beautiful grounds and of that much begabled and rather ornate style that Americans with no good reason term "Queen Anne."

When, in the spring of 1924, the writer visited Menlo, he found a farmer with a tractor plowing neighboring fields; near the station, a factory of keramic tiles; traffic passing on the Lincoln Highway. A dwelling or two lingered from Edison's day. Part of the west wall of the old brick machine-shop stood windowless and forlorn. A rotting car-truck with rusted wheels was settling into the earth; and amidst the bushes one might detect the low embankment where Edison's electric-traction line had run. Fire, the wrecker, and the tooth of Time had left little else to remind one of the Park's decade of fame.

On May 16th, 1925, a memorial was dedicated at Menlo under the auspices of the Edison Pioneers and the Association of Edison Illuminating companies. The dedication exercises included speeches by George S. Silzer, governor of New Jersey, and Dr. John G. Hibben, president of Princeton University. Mrs. Edison unveiled the memorial, which faces the Lincoln Highway [59] and is in the form of a bronze tablet inset in a boulder of native

[59] It stands near the site of the house Edison occupied, and on property held by the Edison Pioneers.

granite. The tablet carries a medallion portrait of Edison and an inscription that reads thus:

ON THIS SITE
1876–1882
THOMAS ALVA EDISON
BEGAN HIS WORK
OF SERVICE FOR THE WORLD
TO ILLUMINE THE PATH OF PROGRESS
AND
LIGHTEN LABOR FOR MANKIND
THIS TABLET IS PLACED BY THE
EDISON PIONEERS TO ATTEST THE
GRATITUDE OF THE INDUSTRIES
HE DID SO MUCH TO CREATE
DEDICATED MENLO PARK, N. J.
MAY 16, 1925

XII

THE MOTION-PICTURE CAMERA; MAGNETIC ORE-MILLING

WHEN Edison first purchased land in West Orange—in a region then half rural, with open stretches of meadow—he was but forty, though already for ten years and more he had been known to familiars as "The Old Man." His cellar laboratory in the Port Huron house had two hundred bottles labeled POISON. The Menlo Park laboratory had been well enough equipped for its purposes and needs. A new mark was set not alone for Edison but for the world by the West Orange laboratory, with its comprehensive special research library and its marvellous stock-room, wherein might be found quantities of almost every sort of material that could possibly be needed in experimenting. To J. Hood Wright of the Drexel-Morgan firm, Edison, when the laboratory was almost completed, wrote of an "ambition to build up a great industrial works in the Orange Valley, starting in a small way and gradually working up."

The first important work in this new environment was the revival and development of the phonograph (previously referred to, in Chapter IX). Up to 1890, the "Improved" or wax-cylinder type was being evolved and, with its blank cylinders, commercially introduced. Thenceforward for many years, other affairs were not so engrossing but that Edison would return to the phonograph and its associated problems and occasionally de-

vote to them periods of intensive effort akin in spirit to the incandescent-lighting era at Menlo.

In the year in which he went to West Orange—1887—Edison, according to his own statement,[1] first began to consider the possibility of an instrument that, as he put it, "should do for the eye what the phonograph does for the ear." By the summer of 1889 he had made such an instrument. His application for a United States patent on it was filed on August 24th, 1891. The patent was not issued until a trifle over six years later—on August 31st, 1897.[2] He called this instrument the "kinetographic camera" or "kinetograph"—that is, a mechanical device that made a graphic record of movement.

The kinetograph depended on a phenomenon with which students had long been acquainted: visual persistence or persistence of vision. In other words, scientists had made intelligent note of the fact that an object continues to be seen by the human eye for an appreciable time after the object has been withdrawn, when the rays of light from it no longer strike the retina. Common examples of this fact were constantly being presented to unphilosophic minds in the so-called flash of lightning, the bright trail of a meteorite, or the fiery line described by the glowing end of a friction match swung rapidly in a dark room. Another example was furnished by the varied forms—three, at least—of an apparatus in which the unphilosophic mind, after the fashion of Peter Bell and the primrose, saw an amusing toy and nothing more.

These three forms, often confused, were the thaumatrope, the phenakistoscope, and the zoëtrope. In the

[1] D. and M., II, 537.

[2] It was later reissued in two parts, dated respectively September 30, 1902, and January 12, 1904.

thaumatrope of J. A. F. Plateau, Belgian physicist, two pictures, either of different objects or of different portions of the same object, were placed at opposite points on the circumference of a disc; and when the disc was revolved, by the unwinding of a string or otherwise, the optical images of the two pictures would be blended, so that the effect was as if both pictures were being seen at once. In the phenakistoscope, two discs were attached at their centers to a common axis—one disc having at fixed intervals on its inner surface a series of pictures illustrating successive phases of motion, the other (and larger) disc being pierced with a corresponding series of narrow radial openings. When the apparatus was held before a suitable mirror and the two discs were swiftly revolved on their axis, each picture would be seen reflected for but an instant and the pictures would all blend into a semblance of continuous movement. In the zoëtrope, a cylinder about seven inches in height, from eight to ten inches in diameter, had around the lower part of its inner surface a series of pictures like that on the smaller disc of the phenakistoscope, and the upper part of its circumference pierced with slits. When the cylinder was swiftly twirled, each visual impression in turn persisted, with the result that the impressions so overlapped as to give the observer an illusion of motion. This form was sometimes called "the wheel of life."

These things were indeed toys, like the kite and the spinning top; but like top and kite, they offered a starting-point for many interesting speculations. The pictures were rather crude line-cuts, poorly printed. The method of observing them was faulty. Nevertheless, possibilities were there suggested. They set Edison thinking.

He has also specifically mentioned his indebtedness to

two experimenters who, in the face of difficult conditions, accomplished much of fundamental value.[3] The first was E. J. Marey of France, who devised the photochronograph and with it made graphic analyses of running, swimming, and walking; showed just how a falling cat manages to land on its feet; conducted, in fact, a whole train of scientific inquiries, some of the results of which he published in a volume that appeared in English under the title "Movement" (International Scientific series). The second was Eadweard Muybridge, pioneer in the United States in the rapid photography of animal motion. Muybridge originally took up this study because of a wager with Leland Stanford of California. Stanford said that a trotting horse at one brief stage in its progress completely left the ground. In order to arrest and examine the phases of movement of a trotter in action, Muybridge hit on the idea of placing alongside a track a row of cameras so arranged that the horse, as it passed, would release the shutters by breaking strings attached to them and stretched across its pathway. Muybridge later photographed the gallop of dogs, the flight of birds, the performances of athletes.[4] It is stated that some of the exposures were for but 1/5,000 of a second. From his negatives Muybridge made positives that could be exhibited by means of what was styled a "zoögyroscope." He mounted them on a cylinder so as to form a kind of zoëtrope, which he spun rapidly inside a magic lantern. The pictures, as projected on a screen, gave the appearance of motion.

For the line-cuts of the zoëtrope, both Marey and Muybridge had substituted photographs of actual motion; but both photographed only a single cycle of movement

[3] D. and M., II, 537.

[4] Iles, "Flame, Electricity and the Camera," p. 312.

because for both the number of exposures was necessarily limited. Furthermore, the object photographed was always in the center of the plate and hence appeared in the center of the image thrown on a screen. The effect of this would be that a moving horse, for example, would be shown in various attitudes but making no headway, while the background sped past—much as in melodramas horses have been run on treadmills while the scenery was briskly unrolled. It is possible that either Marey or Muybridge might have developed a camera that would make a very large number of exposures at a very high rate of operating speed—if only they had not been obliged to use plates! However that may be, the fact remains that after the instantaneous camera and the celluloid film had both arrived, Edison was the first to see how they could be applied to the problem of recording movement. Here we have an example of what many have regarded as Edison's preëminent gift—the ability so to adapt or combine ideas or materials already existing as to effect results at once distinctively new and thoroughly practical.

Marey had been working in the right direction. He used one camera and one lens, thus making exposures from a single viewpoint. But the sensitized surface he employed, though rapid, was presented in the form of bulky, heavy plates; and as each of these plates had, in its entirety, to be started and stopped, the operating speed was relatively slow and the number of exposures per second was relatively limited. Experimenters who in one way or another multiplied the number of lenses, were following the line of greater resistance. This is sufficiently evident now. It was not so evident in 1889.

Edison stuck to one lens and employed a movable sensitized surface. He tried at first a sensitized cylinder in-

termittently revolved, and held at rest for the period of each exposure. The negatives, reduced to microscopic size, were distributed spirally on the cylinder. The positives made from them were examined with the aid of a magnifying glass. Exposures were made at a rate as high as forty-eight a second.[5] The emulsions then available proved too coarse to permit of sharp definition in negatives so diminutive. For this and other reasons, Edison turned from the cylinder to another medium. This was the transparent celluloid roll film, placed on the market in 1889 by the Eastman company. The use of roll film was not a new idea. As early as 1854 a patent was granted in England "for the use of sensitized paper in a roll holder"; and success would in all likelihood have been attained if a proper material had been available for the sensitized surface. "Once the reliability of the gelatine emulsion plate was proven, however, sensitized film coated upon thin paper as a support came into use. About the same time, John Carbutt, the pioneer dry-plate maker in America, introduced cut celluloid films as a substitute for glass plates. The Eastman Company in 1885 brought out a roll holder that could be loaded with a band of paper sufficient for one hundred exposures." . . .[6]

Edison now had in transparent celluloid film a medium at once strong, light, flexible—permitting of rapid-fire exposures and of sharp negatives that were not microscopic but relatively large. The next thing was to provide a mechanism by means of which a tape of film could be so moved across the focal plane of a camera, and exposures could be so rapidly made, that an impression of

[5] D. and M., II, 539.

[6] W. S. Davis, "Practical Amateur Photography" (Boston, 1928; in the Useful Knowledge Books series, edited by G. S. Bryan), p. 17.

continuous movement would be produced by exhibition films (positives) impelled at the same speed ratio. Amateurs that have used the portable film-camera, with its daylight-loading film-cartridge (the invention of the Rev. Hannibal Goodwin, an American experimenter), will readily apprehend the difficulties in the case. They know with what slow care, after an exposure, they have to turn the film-roll ahead, winding it from one spool to the other, before another negative can be obtained.

In the camera mechanism that Edison provided, a long roll ("reel") of film was unwound, drawn through sets of rollers downward across the focal plane and automatically rewound. The strip of film had perforations on its edges. A main-shaft was revolved; this drove a sprocket; the sprocket engaged the perforations; and thus the strip was fed along. The movement of the film was intermittent—that is, periods of movement would alternate with periods of rest. When the film was at rest, a revolving shutter, geared to the main-shaft, was rotated; an aperture in the shutter was brought into the proper relative position; and an exposure was made. Then the film went on its way, while the shutter remained closed. These alternating periods could be repeated indefinitely. The result was a series of "still" photographs—all from one viewpoint, all of uniform size, and all spaced at regular intervals. The only limit to the series was the arbitrary limit set by the length of the film. From twenty to forty exposures could be made.

In experimenting with the kinetograph, Edison was particularly aided by William K. L. Dickson of the laboratory staff.[7] During the summer of 1889 were taken the first examples of motion-pictures as they are known

[7] In 1894 Dickson, assisted by Mrs. Dickson, published "The Life and Inventions of Thomas Alva Edison."

to-day. (It was not until 1890 that Marey adapted film to his uses of scientific study.)

In the laboratory grounds a "studio" was built—a box-like wooden affair so pivoted that it could be turned to catch the sunlight, to admit which a movable portion of the roof was opened. Inside, it was painted black; outside, it was covered with black roofing-paper. Quite naturally it was known as the "Black Maria." Against the somber background of its interior, "La Loie" Fuller danced, "Gentleman Jim" Corbett boxed, fencers contended, bears performed. Mere sequences of movement, these; the day of the "screen drama" was not yet.

Edison also devised an apparatus in which the positive prints made from kinetograph negatives could be exhibited. This he called a "kinetoscope." It was a machine in which the pictures were viewed directly, through an eye-piece. There were a mechanism to move the film-strip, a light to illuminate the strip, and a rotating screen. The screen had a series of apertures in it; these apertures came in line with the eye-piece in such a way that the observer saw only one picture at a time; and persistence of vision did the rest.

When commercial expansion began in the motion-picture field in this country, the work of filming had to be done largely by processes and apparatus on which Edison had obtained patents. His kinetoscope was replaced from 1895 onward by the projection-lantern, a modified and specialized form of the once widely familiar magic lantern. The general arrangement of a projection-lantern was that a powerful illuminating contrivance sent a beam of light through a condensing lens, while the exhibition film (positive) was moved across the path of this beam and at the back of a projection lens. The film was moved intermittently, just as the negative

film had been; and each photograph while at rest was exposed in turn by a rapid shutter. The photographs, when thrown in a much enlarged form upon a screen, so blended as to give an impression of continuous action. That is to say, they were supposed to do so; but, through one defect or another, they would often jump and glint most distressingly. There was pretty steady improvement in this respect, as in other purely mechanical features of motion-picture taking and projecting—but to enter into a history of the "movie" industry is hardly within the province of this volume.

Rear-Adm. Bradley A. Fiske, U. S. Navy, has written [8] that in the kinetograph and kinetoscope "we see an invention of the highest order in each of the three essentials—conception, development and production. No invention exists of a higher order." As to the modern motion-picture, he says: "Whether it is for the public good to produce so many shows for idly disposed men and women to spend their time in looking at, is perhaps a possible subject for enlightening discussion. But the moving picture is used for many purposes, especially for purposes of education and research, besides that of mere amusement, and will unquestionably be so used, more and more as time goes on."

From the very beginning, Edison evidently thought highly of the educational possibilities of motion-pictures, both for popular audiences and in the class-room. Most educators would probably agree that motion-pictures might be made a valuable accessory to the text-book and the living teacher. Few, however, cared to follow Edison in his reported statements (1923) that "in twenty years children will be taught with pictures and not with books" and that "Motion pictures are 100 per cent perfect for

[8] In his "Invention" (New York, 1921).

disseminating knowledge."[9] Oral instruction, books, maps, pictures other than motion-pictures—these, it was generally believed, would hold their place if education was to have a properly broad meaning; and nothing could diminish the importance of constructive thinking and real study.[10]

More generally approved, doubtless, were these other words of Edison, written to be read at a dinner given to him in New York by members of the motion-picture industry on February 15th, 1924, to honor his seventy-seventh birthday:

". . . Whatever part I have played in its [*i. e.*, the motion picture's] development was mainly along mechanical lines.

"The far more important development of the motion picture as a medium for artistic effort and as an educational factor is in your hands. Because I was working before most of you were born, I am going to bore you with a little advice.

[9] "New York Tribune," May 16, 1923. Possibly Edison's views were somewhat exaggerated. See William Inglis' "Edison and the New Education," in "Harper's Weekly" for November 4, 1911 (p. 8).

[10] A factor to be considered has thus been pointed out:

". . . You seem to imply that the manufacturers have produced subjects and the educators are backward in using them. Quite the reverse is the case. The educator during the last fifteen or twenty years, to my knowledge, has been appealing to the manufacturers to produce subjects suitable for class-room work, and the manufacturers have failed to respond to the call, chiefly owing to the mistaken idea that they cannot make millions in educational subjects.

"According to a recent report of the Commissioner of Education, there are thousands of schools equipped with projecting machines, but they can get nothing suitable to project, consequently many of them are lying idle and a majority of these machines are consigned to the basement of the schools to rust owing to the paucity of suitable subjects for the classes."—From a letter of Alfred H. Saunders, lecturer and writer on educational cinematography, in the "New York Tribune," May 22, 1923.

"Remember that you are the servants of the public and never let a desire for money or power prevent you from giving the public the best work of which you are capable."[11]

Back in 1880—the year in which he was making ready to introduce his system of distributing electric current—Edison had obtained a patent on a magnetic ore separator. Several other inventors, especially during the latter half of the nineteenth century, had attempted to concentrate the iron in low-grade iron ores by magnetically separating the iron portion from the gangue—"gangue" being the mining term for the veinstone or rock occurring with the ore. Edison took up the idea because he was aware that the iron-mills and steel-mills of the East were being affected by the scarcity of high-grade iron ore and the increasing prices.

In 1881 he established a small concentrating plant at Quogue, on the south shore of Long Island, where, upon the beach, he had found a huge deposit—"hundreds of thousands of tons," he judged—of so-called black sand, particles of extremely pure magnetic iron. Hardly had the plant been started when, said Edison, "a tremendous storm came up, and every bit of that black sand went out to sea." W. H. Meadowcroft in that year, under Edison's direction, set up on the Rhode Island coast a plant of similar kind. In this case over 1,000 tons of excellent iron concentrate were separated and sold; but the concentrate, as was later discovered, was too finely divided and hence it could not be used with success.[12] Edison subsequently invented a method for dealing with such finely divided ore.

[11] "The World," February 16, 1924.

[12] Meadowcroft, p. 242.

From 1881 until 1891, ore-concentrating was in abeyance; from 1891 to 1900 it claimed most of Edison's time and effort.[13] With the aid of a specially constructed magnetic needle, he located a vast ore deposit in the mountain region of northern New Jersey, in Sussex county. There he built a concentrating works representing a notable achievement in industrial engineering. In its outlines and general scope this was one of Edison's largest enterprises, yet it was one with which the public is little acquainted. In it over $2,000,000 were invested, of which Edison himself furnished the greater part—the bulk of his private fortune. Around the works, in the midst of a wild and wooded country, grew up a village called Edison, to which the Central Railroad of New Jersey built a branch line from Lake Hopatcong. The workers' houses, of a type designed by Edison himself, had running water and were lit by incandescent lamps. In this unusual mining town Edison for about five years spent the working days of each week, going to "Glenmont" for Sundays only. The dwelling in which he lived was locally known as the "White House." In 3,000 acres lying immediately around the works were—so he reckoned—some 200,000,000 tons of low-grade ore; and to this tract he added 16,000 acres containing ore, he thought, in the same proportion.

The core or center of the whole undertaking was the magnetic separator, employed on a bold scale. Around this he developed a series of inventions designed to make it possible to concentrate about 6,000 tons of ore a day. Blasting dislodged 30,000 tons or so of rock at a time. Great steam-shovels loaded the rock upon skips, and the skips were hauled over a narrow-gauge railway to the

[13] This is witnessed by the list of patents applied for during these years. See also D. and M., II, 501.

"giant rolls." Each of these two solid cast-iron rolls was five feet long and six feet in diameter, and their combined weight was 167,000 pounds. They were set about fourteen inches apart and belt-driven in opposite directions, the power being applied through friction-clutches by means of which it could quickly be connected or disconnected. Engineers didn't think the scheme would work, but it did.

A rock the size of an upright piano and weighing, maybe, five to eight tons, was raised from a skip and swung over a hopper above the rolls. The rolls were speeded up to something like a mile a minute—then the power was disconnected. Down dropped the rock into the maw of the rolls. There was no strain on the engine; the rolls were running under their own momentum. With the shock of a gigantic pile-driver and a deafening crash, the rock passed between the rolls, coming out at the bottom in pieces small enough to get through the fourteen-inch gap.

These pieces were broken by a progressive series of "intermediate rolls" into bits about the size of an ordinary marble. Then the bits were pulverized in a grinding machine known, from its peculiar construction, as the "three-high rolls." This machine, which exerted a pressure of 125,000 pounds with an amazingly small amount of friction, had three cylinders, each about three feet in diameter, set vertically in a frame. The shaft of the bottom cylinder ran in fixed bearings, but the shafts of the middle and top cylinders ran in loose bearings and could move up or down. The bits of rock passed first between the top and middle rolls, then between the middle and bottom rolls. At either end, outside the frame, the shafts of the top and bottom rolls carried a seven-grooved sheave. An endless wire rope went around these sheaves

and was carried up over a single-grooved sheave that was controlled by the piston of an air-cylinder. As the piston was either raised or lowered, a varying pressure could be exerted on the top and bottom rolls, the bearings of which revolved inside the turns of wire rope. In this way another set of bearings was in effect supplied by the rope; and thus friction was reduced to such an extent that the "three-high rolls" showed a working efficiency of 84 per cent. (with a loss of only 16 per cent.). Up to that time the best available grinding machines had shown a working efficiency of but 18 per cent. (with a loss of 82 per cent.)—practically the reverse of what Edison proved might be accomplished.[14]

Drying and screening also entered into the process; and the pulverized material journeyed past four hundred and eighty magnets so grouped in series that the successive magnetic fields were increasingly powerful. Non-magnetic particles fell in a straight line. Magnetic particles were drawn toward—not to—the magnet. Their path was altered because they were acted on by both gravity and magnetic force. The non-magnetic particles were acted on by gravity only. Thus the two kinds of particles were separated; and they proceeded by their respective routes to the opposite sides of a divided bin. The non-magnetic particles, constituting the tailings (*i. e.*, the débris of the process), were sold for various industrial purposes—especially for use in mortar, to which they were well adapted. The magnetic particles were mixed with a binder and compressed into briquettes one and one-half inches thick and three inches in diameter at the rate of sixty a minute. These briquettes were hard enough to stand shipment; waterproof enough to shed the weather when, for the sake of lower freight rates, they

[14] D. and M., II, 916–918.

were shipped in open cars. At the same time they were porous enough, when used at the smelting-works, to allow of proper action by furnace gases. They ran 2,800 to a ton; and in 1897 the plant was daily averaging seventy-five car-loads of twenty tons each.[15]

In Edison's ore-milling process, approximately 100,000 cubic feet of material a day were put through, travelling about a mile. This was made possible by means of skilfully designed conveyors. Edison's plans were based on low costs through automatic transfer. The proportion of tailings to high concentrate ran about three to one—that is, three tons of the first to one ton of the second. In the concentrate, the final percentage of iron oxide averaged from 90 to 93 per cent.

All the links of the chain were strong. Vast deposits of low-grade ore were close at hand. The milling process was remarkably efficient and economical. The product showed high quality on test. John Fritz of the Bethlehem Steel company had ordered 10,000 tons of it. Then something unforeseen and unpreventable happened. In the Mesaba hills of north-eastern Minnesota, enormous and easily accessible deposits of uncommonly rich Bessemer ore were discovered. What with the richness of this ore and the low cost at which it could be mined, the price of crude ore of that quality dropped to around $3.50 a ton. At from $6.00 to $6.50 a ton, Edison would have been able to sell his briquettes profitably. At $3.50 a ton, it was out of the question for him to seek to compete. Engineering problems had been solved. Precedents had been successfully flouted. The mill was nonchalantly turning out cakes of magnetite. With the goal of some nine years' work practically in view, it seemed

[15] See Theodore Waters, "Edison's Revolution in Iron Mining," in "McClure's Magazine" for November, 1897; pp. 75–93.

best for prudential reasons to abandon the enterprise. The company was in debt to the extent of several hundred thousands of dollars, but in about three years all debts were paid. The mill was closed; its workmen drifted away; their cottages tumbled in ruin or were torn down for the lumber they contained; the plant was gradually dismantled. Before many years had gone by, a wanderer in those parts, chancing upon that remote cluster of weatherbeaten and decayed buildings, might have wondered of what ambitious labors it had been the scene.

Hardly had the works been closed when Edison was planning to take up the manufacture of Portland cement, as he was convinced that in the cement industry much of what had been learned in the venture of ore-milling could be successfully applied. Practically all the mechanical equipment of the ore-milling works, with the exception of the separators and the devices for mixing and briquetting, was later adapted to cement-making. For example, the "three-high rolls," which originally had smooth faces, were altered for the cement process (in which the feed was more rapid) by being meshed together in the style of gears. Edison also set out to develop a wholly new type of storage battery. To R. H. Beach of the General Electric company, he said, "Beach, I don't think Nature would be so unkind as to withhold the secret of a *good* storage battery, if a real earnest hunt for it is made." . . .[16]

W. S. Mallory, a business associate of Edison in the ore-milling project and afterward in the cement company, related that in 1902, in which year the stock of the Edison General Electric company[17] touched its high

[16] D. and M., II, 554; Meadowcroft, 275.

[17] See Chapter XI, p. 181.

figure, Edison asked him, "If I hadn't sold any of mine, what would it be worth to-day?" Mallory did some reckoning on the basis of the day's quotation and answered, "Over $4,000,000." After a few seconds' pause, Edison cheerily remarked, "Well, it's all gone, but we had a hell of a good time spending it." [18] One summer day in 1910 he visited the ruinous separating-plant. Seated on the "White House" porch, he said only: "I never felt better in my life than during the five years I worked here. Hard work, nothing to divert my thought, clear air and simple food made my life very pleasant. We learned a great deal. It will be of benefit to some one some time." [19]

In 1889 Edison and Mrs. Edison visited the Paris Exposition, at which the Edison exhibit, comprising seventeen departments, covered over 9,000 square feet of floor space. This exhibit, made at the inventor's personal expense and costing upwards of $100,000, was installed under the supervision of W. J. Hammer, Edison's representative, with the aid of forty-five assistants.[20] Edison had a chat with Pasteur and inspected the newly completed Eiffel Tower in the Champ de Mars as the guest of Alexandre Eiffel, the French engineer who designed and constructed it. In Eiffel's private office at the top of the tower, Gounod, then seventy-one, played and sang for the Edison party. Many honors were shown to Edison, including dinners given by the French engineers and by the municipality of Paris. He also attended a gala performance at the Opéra, where, as he entered his box, the orchestra played "The Star-Spangled Banner" and the house rose—"whereupon," said he, "I was very much

[18] D. and M., II, 504–505.

[19] *Ib.*, II, 776.

[20] On February 10, 1925, Major Hammer was decorated chevalier of the Legion of Honor, in belated recognition of his services to France in 1889.

embarrassed." At the close of the exposition, Edison was made a commander of the Legion of Honor. ". . . They tried to put a sash on me," he is quoted as relating, "but I could not stand for that."[21]

[21] D. and M., II, 748.

XIII

MAKING PORTLAND CEMENT; BUILDING A NEW STORAGE BATTERY

In establishing his Portland cement mill at New Village, New Jersey, Edison was entering no new industry but one that had been in existence for three-quarters of a century. It was in 1825 that Joseph Aspdin, brickmaker of Leeds, England, invented Portland cement—the name coming from its supposed resemblance to Portland stone, a limestone much used in England and obtained from the Isle of Portland (Dorset). Natural cements—that is, cements made through the burning and pulverizing of limestones naturally containing clay—were found to be inferior to Aspdin's, which in masonry permitted a freer use of sand, set more gradually, and developed greater strength. The Portland cement was made by burning a specially prepared mixture of limestone and clay, in which the proportions of each could be absolutely controlled. Judged by later standards, the earliest cement of this kind was of a crude sort.

In 1872, nearly a half-century after Aspdin had invented it, Portland cement was for the first time produced in the United States—the pioneers being David O. Saylor of Coplay, Pennsylvania, and his associates, Adam Woolever, Esaias Rehrig, and Willoughby Focht. It was not long before the natural cements, which had been in favor ever since the engineer Canvass White had used such material in the building of the Erie canal, encountered a rival in the new product. By the beginning of the

twentieth century, Portland cement was much preferred —how much, may be indicated by the fact that in 1902 the Portland cement production in the United States was 17,230,644 barrels, valued at $20,864,078, whereas natural-rock cement production for that year was 8,044,-305 barrels, valued at $4,076,630.[1] The machinery used in the making of Portland cement had become increasingly efficient, and the quality of the output had steadily risen.

In this field, then, Edison appeared as a newcomer. He had seen the marked growth of the industry and had noted how widely the use of concrete was being extended for structural purposes. His ore-milling venture, now come to an unavoidable end, had given him valuable experience in matters connected with the crushing and grinding of raw rock. For it he had developed special machinery that might be adapted to the process of cement manufacture. Nature had compelled a retreat on his part, but even in retreat he displayed the strategy of a good general.

It is said that after Edison had "with the greatest possible reluctance"[2] concluded to shut down the separating plant, he took the next train home; and during this railway journey decided that while he was experimenting with a new storage battery, cement-making as a "side-line" would help to pay old debts even though it might not recoup him for old losses. Talking to Mallory, Edison "most positively" stated that "no company with which he had personally been actively connected had ever failed to pay its debts, and that he did not propose to have

[1] H. H. Saylor, "Tinkering with Tools" (Boston, 1924; in the Useful Knowledge Books series, edited by G. S. Bryan), pp. 190–191; A. A. Hopkins and A. R. Bond, *ed.*, "The Scientific American Reference Book" (New York, 2nd ed., 1906).

[2] Mallory as quoted in D. and M., II, 502.

the Concentrating Company any exception."[3] He did not think that at that stage the phonograph works would yield profits sufficient to carry the burden.

His method of approach to cement-manufacture was characteristic. He read extensively on the subject and collected data from many sources. Then he plunged into the task of construction. It seems that, working all day and far into the night in a draughting-room of the West Orange laboratory, he drew at one sitting a plan for the New Village plant—drew it so well from end to end that after ten years of use "no vital change," so we are assured, was needed.[4] This was no mean feat, but it was perhaps equalled by one connected with the time when the plant—built entirely of steel and concrete—was about ready. Edison spent the greater part of a Saturday in a thoroughgoing inspection. That evening at "Glenmont," without notes to refer to, he began to write out a list of each and every detail that he had examined at the plant, with specifications of changes to be made in certain machinery. He worked straight through to Sunday afternoon, when he finished the list—in all, close to six hundred entries. A copy of this was sent to the general superintendent and used by him in making the changes Edison required.[5]

In the manufacture of Portland cement, the ground mixture of raw material is fed into revolving kilns in which an intense heat is maintained through powdered coal kept burning inside them. When acted upon by the heat, the mixture softens and forms "clinker"—not the clinker of the householder's furnace or stove-grate but spheroids that roll out at the other end of the kiln.

[3] D. and M., II, 503.
[4] *Ib.*, II, 509.
[5] *Ib.*, II, 518–519.

Cooled, finely ground, and screened, these spheroids yield cement powder, which is then packed in barrels or bags. Such, briefly, is the general process.

Edison devised a weighing arrangement by which, when the beam was tipped, an electric connection was broken and the hopper was automatically closed. This was used in keeping the relative quantities of raw materials precisely uniform. He also provided for finer grinding and planned an oil-circulating system that took care of no less than 10,000 bearings. His chief novelty was the "long kiln." For the regular kiln, with a length of some sixty feet and an inside diameter of five or so, he substituted one having a length of a hundred and fifty feet and an increased diameter. He claimed that with this larger kiln he could economically treat a greater amount of raw materials and turn out a better grade of cement. The average sixty-foot kiln would yield approximately two hundred barrels of clinker for every twenty-four hour day. The "long kiln" raised production to a maximum of more than 1,100 barrels in every twenty-four hours, although a rate somewhat below full capacity was fixed upon for the sake of economy.

Lesley, in his "History of the Portland Cement Industry,"[6] says: "In 1909 Thomas A. Edison was granted a patent for the use of kilns 150 feet and longer, every one predicting that it would be impossible to turn kilns of this length without warping. The proof of the pudding, however, was in the eating, and it was not long after Edison's invention that kilns of 125 feet became almost standard as substitutes for the old 60-foot kiln. Mr. Edison not only designed the long kiln described, but was the first to use steam shovels for loading rock in the quarries. He also introduced the well-drill in quarry op-

[6] Pp. 123–124.

eration. Later on the length of the Edison kiln was far exceeded. Some kilns now in use are 260 feet long, with capacities of a thousand or more barrels of cement per day."

Edison's excursion into cement-making is of interest less for what he contributed to standard practice than for glimpses it affords of the man—of his energy, his mental grasp, the individuality that would question accepted ways and study ways of its own. If he did not revolutionize the cement industry, he placed his impress upon it. His associate Mallory is authority for the statement that within about ten years over half of the total amount of Portland cement made in the United States was burned in long kilns.[7] Though it may be true that by 1910 the directors of the older companies were no longer so concerned as they once had been over Edison competition, it is also stated that by that time the Edison Portland Cement company had gained fifth rank among American producing companies. In 1905 the capacity[8] of the works was 3,000 barrels daily; in 1924 it was 7,500 barrels daily.

During these earlier years of the cement plant's development, Edison was working upon cylindrical phonographic records; upon an improved form of the business phonograph, the new feature of which was that dictated matter could be repeated and corrections might thus be made; upon an electric motor for operating the business phonograph (or dictating machine) on commercial electric-lighting circuits. His chief interest at this period was, however, centered in his long and arduous campaign to realize his idea of an alkaline storage battery.

[7] D. and M., II, 514.

[8] D. and M., II, 698; R. W. Lesley: "History of the Portland Cement Industry" (Chicago. 1924).

This storage battery was probably the hardest nut he ever tried to crack.

Like all other electric batteries whatsoever, the so-called storage battery derives, of course, from the primary battery—better known as the voltaic battery, since the principle of its action was discovered by Alessandro Volta. A primary battery is composed of a group of primary cells. Broadly speaking, a primary cell has for its component parts two different metals (known as the elements) associated with a chemical compound (termed the electrolyte). In the simple form of its modern development, the primary cell has a piece of zinc and a piece of copper dipped into a solution of dilute sulphuric acid. A chemical action is set up; the zinc piece is gradually dissolved away; electric energy is produced. More complex in structure is the "dry" cell, generally familiar through its use for electric bells, for flashlights, in motor-boats and motor-cars, and in radio receiving-sets. "Dry" it is not, except in a relative sense. Its cylindrical zinc container is the negative element; through the center of this runs the positive element, a carbon (non-metallic) rod that takes the place of the second metal. Inside the container and around the rod is tightly packed a mixture of graphite, granulated carbon, and other materials; and this mixture—the electrolyte, corresponding to the acid solution of the zinc-copper cell—is *moist*, and must be. In both of these forms, a metal dissolves away and this chemical action yields an electric current.

The chemical action of the primary cell is irreversible. What is meant by an "irreversible" chemical process? ". . . Let us fry an egg over a gas-jet; no cold, however intense, can unfry it, and no electric current, however strong, can restore it to its first estate."[9] A

[9] Iles, "Flame, Electricity and the Camera," p. 144.

reversible chemical change is one like the decomposition of water into two elements, hydrogen and oxygen. After this has been accomplished, the two elements will again unite to form water. The action of the so-called storage battery (or group of storage cells) is reversible; and "reversible battery" is a better though less popular term. "Storage battery" suggests that electric energy is stored in the apparatus; and such is not at all the case. "Secondary battery" is satisfactory; it indicates the important fact that in its original form this type of battery will not, like the primary battery, yield electric current. Only after current from some outside source has charged it, is the so-called storage battery prepared to function.

When Edison in 1900 began his hunt for the secret of a "good" storage battery, it was the battery of lead-sulphuric acid type that held the field. This battery, greatly improved since that time, is familiar in its three-cell form to drivers of motor-cars with internal-combustion motors. The general principle of the storage-battery was known at least as far back as the early years of the nineteenth century, but the first important forward step was not taken until 1861, when Gaston Planté arranged plates of sheet lead in a solution of dilute sulphuric acid. Another advance was recorded in 1879, when Émile Faure brought out his "pasted-plate" type. In 1881 Charles F. Brush (to whose arc-lighting system reference has already been made)[10] introduced certain improvements, and with this stimulus the lead-sulphuric acid battery really entered its commercial stage in the United States.

The Planté type as first assembled has plates of sheet lead—pure metallic lead—and the solution (electrolyte) of dilute sulphuric acid. The plates have to be "formed" —that is, an electric current has to be passed through

[10] See Chapter X, p. 106.

them repeatedly in alternate directions. This results in producing lead monoxide at the surface of the plates. At the same time, through the action of the acid, the surface of the plates is covered with lead sulphate; and this, since it is practically insoluble, furnishes to the metal a protective covering that very largely prevents losses from local action. Now let the cells be charged—say, from a dynamo. It will then be found that whereas two plates were previously of the same material, they now have suffered a "sea-change"; at the surface of the positive (cathode) plate is lead peroxide, hard and of a reddish color; at the surface of the negative (anode) plate is metallic lead, spongy and gray. The Faure type eliminates the long and costly process of "forming." In this type, oxide of lead—either lead monoxide or red lead—in the fashion of paste is at the outset applied to the plates. Then when the battery is charged, the current transforms the surface of the positive plate into lead peroxide, the surface of the negative plate into metallic lead.

Briefly put, then, a charging current produces different effects in the positive and negative plates. If now the charging current is withdrawn and the battery is connected in circuit, the two plates act as two different metals do in the primary (or voltaic) cell: they set up a current. This current is reverse in direction to the charging current. Hence the term "reversible battery." It is chemical energy that is accumulated in such a battery (hence the term "accumulator," used in Great Britain); but this chemical energy can be delivered in altered guise as electric energy.

This preliminary survey will perhaps help to make clear what Edison was trying to do and how radical were his departures in battery construction. It is said that

back in the early 'eighties at Menlo he made many experiments looking toward the improvement of the lead-sulphuric acid type, which even then he was inclined to regard as "intrinsically wrong."[11] This attitude kept him from seriously considering that type as an adjunct to his incandescent-lighting system. For incandescent lighting, a ton of coal, he said, was the best storage battery he knew.[12] When he started to hunt for a "good" battery, he was sure of two things: it was not to use lead, and it was to have an alkaline solution instead of an acid one. Otherwise, he could be certain of nothing.

Among the defects of which he was aware in the lead-sulphuric acid type were the narrow restriction as to materials for containers; the tendency of the plates to buckle if in use when the electrolyte happened to be low; the dropping of fine particles to the bottom of a cell; the great weight, relative to electric capacity; likelihood of injury through overcharge, through extreme or complete discharge, or through remaining uncharged. The sulphuric acid, too, gave out corrosive fumes, and it had the defect of its quality of attacking and decomposing practically everything with which it came in contact.

The battery he purposed to develop was to be used to supply motive power—chiefly for road vehicles, to some extent for street-railway cars. The job took about ten years of work by himself and a selected staff. Over 10,000 experiments were made before any definitely encouraging results were won. Then iron and nickel promised the electric action that he sought. But this was only the beginning. He had a clue, indeed, but the

[11] D. and M., II, 927.

[12] D. and M., II, 553.—Storage batteries came to be used widely in connection with the larger lighting-systems and traction-lines. Current turned into batteries at slack times could be released during busy periods, to lighten the load on the generating plant.

way was long through the labyrinth. Once it seemed that he had arrived, but this was a mistake; the journey had to be resumed. All told, about 50,000 experiments (the record of them filling over a hundred and fifty of the laboratory note-books) were demanded before the goal was achieved.

The complexities of this battery problem were tremendous. To J. W. Aylesworth, his chief chemist, Edison remarked, "In phonographic work we can use our ears and our eyes, aided with powerful microscopes; but in the battery our difficulties cannot be seen or heard, but must be observed by our mind's eye!" [13] There was need of all the old patience, all the old tireless persistence. At midnight Edison's carriage would be waiting to take him to "Glenmont"; but often it continued waiting until two or three in the morning, and at times it went back without him. From those earlier years of battery work—marked, like the incandescent-lamp period at Menlo, by long wakefulness, short sleep, and suppers at midnight—emerges the figure of Edison ensconced for a nap in a roll-top desk. His head reposes on two or three volumes of Watts' "Dictionary of Chemistry." (Around the laboratory, a standing joke is that he is thus directly assimilating their contents.) He turns over, but without danger—he never tumbles. When he wakes, he wakes at once, evidently holding, with Secretary Chase, that the way to resumption is to resume.

One day, when work on the storage battery had been under way for over five months and more than 9,000 experiments had been made, Mallory found Edison sitting at a laboratory bench covered with test cells. Nothing of promise had yet been reached. Mallory expressed condolence: "Isn't it a shame that with the tremendous

[13] D. and M., II, 563.

amount of work you have done, you haven't been able to get any results?" "Results!" Edison smilingly flashed back—"Why, man, I have gotten a lot of results. I know several thousand things that won't work."[14] It was not long before he hit upon something that did work.

The nickel and iron that he used were in chemical forms—nickel hydrate and iron oxide. At Silver Lake, about three miles from the West Orange establishment, he built works for the manufacture of these materials. At last he felt that commercial production of battery cells might be started. The original battery was known as "Type E." Though higher in first cost than a lead-sulphuric acid battery of corresponding output, it was well received and extensively purchased—not only because of Edison prestige and the newspaper announcements but also because results showed that it was cleaner, lighter, cheaper to maintain, and marked by the property—quite lacking in the lead-sulphuric acid battery and of decided value from the user's viewpoint—of remaining uninjured when either overcharged or left uncharged. The cells were made according to Edison's rigorous standards of quality, with high-grade materials and uniform care.

After a while, however, evidence showed that for some reason or other the cells would now and again be of defective capacity. Assured of this, Edison saw that the logic of the situation was simply that as more cells were manufactured, more batteries would prove inferior. Though he knew that if production were suspended a large financial loss would be involved and the common impression would be that the battery was commercially a failure, he at once ordered that the factory shut down and announced that he would attempt to improve the old

[14] D. and M., II, 615–616.

cell so as to give it increased capacity and a longer life. Re-orders from satisfied purchasers were not accepted. It made no difference that "considerable pressure was at times brought to bear"[15]—presumably by leading stockholders. As a contrast to the all-too-frequent spectacle of imperfect products forced upon the market by the dodges of advertising, this attitude on Edison's part is, to say the least, refreshing.

A second course of experimenting was straightway in full blast. This resulted in the "Type A" battery, described by one of Edison's laboratory assistants as "a finer battery than we ever expected." ". . . Secrets," declared this man, "have to be long-winded and roost high if they want to get away when the 'Old Man' goes hunting for them." Manufacture of the new type, begun in the summer of 1909, was being extended within a year.

For this vehicle battery three sizes of cell were made. These were known as A-4, A-6, and A-8—the numerals indicating the number of positive plates that each contained. Both of the outside plates were negative, so that the cells had respectively five, seven, or nine negative plates. The dimensions of the plates were identical for all cells; hence the one variation was in the thickness of the container or can, which was less or greater according to the number of plates. The cells were assembled in a wooden tray of light weight and strongly built. In the standard assembled battery, the pounds per cell were: A-4, 14.21; A-6, 20.09; A-8, 26.15. It was claimed that a vehicle battery when assembled weighed but little more than half as much as a lead-sulphuric acid battery of corresponding output.

A cell might be divided into four component parts: (*a*) The electrolyte, a 21-per cent. solution of caustic

[15] D. and M., II, 567.

potash (pure potassium hydrate) in distilled water;[16] (*b*) a group of positive plates connected in multiple with the positive terminal; (*c*) a group of negative plates, similarly connected with the negative terminal and intermeshed with the group of positive plates; (*d*) a container (or can) of nickel-plated sheet steel.

During the cycle of charge and discharge, the electrolyte remained unchanged with respect to specific gravity, conductivity, and the proportion of potash to water. Also, because the plates were immersed in a solution that was stable and non-injurious to metals, the cell might be left unused, either partially or wholly discharged, for a considerable time.

A positive plate was composed of a nickel-plated steel grid holding thirty tubes, each four and one-eighth inches long and with a diameter of a quarter-inch (or about that of the ordinary lead-pencil), arranged in two tiers of fifteen and packed with the positive active material, nickel hydrate. It was lack of adequate electrical contact in these positive pockets that had caused Edison to be dissatisfied with "Type E," and that led to experiments lasting about five years and costing more than a million dollars. The tubes of "Type A" were of very thin sheet steel and perforated with minute holes, through which the electrolyte could seep. Into these tubes were packed, under a pressure of about four tons to the square inch, layers of nickel hydrate and of the material that finally solved the contact problem—nickel-flake. The thinness of these layers may be judged from the fact that it required about seven hundred of them—about three hundred and fifty of each material—to fill a tube.

[16] A small amount of lithium hydrate was also used. In November, 1923, the newspapers stated that Edison had purchased a spodumene mining lode in the Black Hills, Nebraska. Spodumene (or triphane) is a lithium-bearing mineral.

Nickel flake was made of pure nickel by an electroplating process [17] in which a hundred layers of copper and a hundred layers of nickel were deposited alternately upon a metal cylinder, then removed in sheet form and placed in a bath that dissolved away the copper. A handful of discs of this nickel flake would be as light as feathers. A bushel of them weighs only four and one-half pounds. When inserted in a tube, the discs made excellent contact with it and were conductors of current to and from the nickel hydrate. In order to prevent any expansion that might interfere with this contact, the tubes were made with a double-lapped spiral seam and over them were slipped metal rings.

A negative plate was composed of a grid holding twenty-four flat, rectangular pockets, perforated like the positive tubes and arranged eight in a row. The negative active material was an iron oxide quite like ordinary iron rust. Sheets of perforated hard rubber insulated the two end (negative) plates from the walls of the container. Rods of it separated adjacent plates, and cross-pieces of it held the plates above the bottom of the can—only slightly, however, as the loss of active material was never more than trifling. The container had its walls corrugated to some extent in order to provide the utmost rigidity with the least possible weight.

In a certain few respects this nickel-iron battery required somewhat particular care. The amount of electrolyte was relatively small. Hence the cells showed a greater tendency than did lead cells to heat suddenly

[17] Under date of 1924 the monograph "The Edison Alkaline Storage Battery" (National Education Association Joint Committee series, Monograph III) stated that according to the practice at that time, tubes were four and one-half inches long and about six hundred and thirty layers were packed under a pressure of 2,000 pounds to the square inch. In the electro-plating, one hundred and twenty-five films of each metal were deposited.

through excessive current; and the electrolyte tended to evaporate. Also, the small amount of electrolyte and the metal cans combined to make the cell more susceptible to cold than was the lead cell. These matters were, however, regarded as of slight importance in comparison with the many advantages offered by the battery for electric-vehicle work—such as longer life, markedly lighter weight, lower maintenance cost, and more than double mileage per charge in road performance. In other words, the "good" storage battery that Edison sought seemed to have been found.[18]

The story of the Edison battery is one of insistent plodding—quite devoid of spectacular features such as were not lacking, for example, in the work on the incandescent lamp. As illustrative of Edison's traits and methods, it has, however, much interest. A co-worker during those ten years asserted, "If Edison's experiments, investigations, and work on the storage battery were all that he had ever done, I should say that he was not only a notable inventor, but also a great man." [19]

The nickel-iron battery turned out to be peculiarly well adapted to a field not taken into account in its inventor's original plans—the field of submarine service. Whatever might be thought of the possibilities of the submarine as an element in warfare (for great argument prevailed regarding this), it was generally agreed—and especially by those with experience—that for human sojourn a submarine's interior left much to be desired, and particularly when the vessel was submerged. When at the surface of the water, the submarine was driven by internal-combustion engines. The air inside it could then

[18] J. B. Baker, "Thomas A. Edison's Latest Invention," in the "Scientific American" for January 14, 1911.

[19] D. and M., II, 555.

be kept pure. When submerged, the vessel was driven by electric motors. Access of outside air was then, of course, impossible. A supply of chemically pure compressed air was carried in steel tanks, and a system—complicated at best—was tried for withdrawing the air from the vessel's interior, to which it was later returned filtered, cooled, and with the oxygen restored to it. These means did not, however, eliminate the poisonous fumes of the lead-sulphuric acid storage batteries.

The batteries supplied current for the motors that drove the propellers when the boat was submerged, and also for auxiliary motors used in managing torpedoes, in steering, in pumping. When minute bubbles of gas—oxygen from the positive plates and hydrogen from the negative—rose to the surface of the electrolyte, passed through the open gas-vent of a cell, and floated away, each carried its tiny load of sulphuric acid, to be released in fumes when the bubble broke or was evaporated. After a while—often without odor sufficient to attract attention—the air within the boat would become so tainted as to cause coughing and sore-throat among the crew. This was bound in time to affect the lungs and general health. More serious yet, if salt water in any way came into contact with a battery, chlorine gas would be formed, offensive to smell and extremely harmful to those who breathed it. Lead-sulphuric acid batteries had also to be installed with elaborate provision and consequent expense, lead-lined rooms and lead-lined ventilating pipes being part of the specified equipment.

The Edison nickel-iron cell had a check-valve instead of an open vent; and in order for the bubbles to escape, pressure enough to lift the valve had to be developed within the cell. Even if the bubbles did escape, no harm could be done, because caustic potash was what the

electrolyte of this battery held in solution, and potash is (as is well known) an excellent disinfectant. Nevertheless, for submarine use Edison provided the battery with a special device that completely removed potash from the gases. The Edison battery required no lead-lined rooms or other protective equipment. Uncommonly severe tests proclaimed its sturdiness. Edison vouched for its long life. "Keep it clean," he said to officials of the United States Navy, "and give it water and at the end of four years it will give its full capacity." And when they queried with surprise, "Four years?" he answered, "Yes. Four years, eight years; it will outwear the submarine itself." [20]

The Edison storage cell was also adapted to battery use with radio broadcast receiving-sets. For this purpose, the assemblies were of a special type. It was claimed that these batteries would outlast three to six radio storage batteries of any other make.

[20] C. W. Williams, "Edison Solves Submarine's Problem," in the "Technical World Magazine" for February, 1915.

XIV

LATER INVENTIONS; SERVICES TO THE GOVERNMENT

From the appearance of his "Type A" nickel-iron storage battery until the outbreak of the World War, Edison was concerned chiefly with the development either of his existing inventions or of new inventions derived from these. For example, he was perfecting his disc phonograph—seeking, with excellent results, to get rid of certain mechanical flaws and to approach more closely to an artistic re-creation of instrumental and vocal tones.

In 1912 he introduced the kinetophone, which had its origins in two prior inventions of his, the phonograph and the motion-picture camera. He had now, wrote I. F. Marcosson, "finally realized a dream of many years by linking two marvels of his genius." . . . The kinetophone became popularly known as the talking motion-picture.

"The kinetophone," said Edison, "or rather the synchronization of sight and sound, is an old idea of mine that has finally been realized. In one way or another it had been in mind for more than thirty years. Back in the late seventies, when I invented the phonograph, it was stirring, and in 1887, when I was able to perfect the motion-picture camera, that idea of a combination of sight and sound persisted. Some of my earliest experiments in sound included an attempt to work it out.

"The problem of actual synchronization was the least difficult of my tasks. The hardest job was to make a

phonographic recorder which would be sensitive to sound a considerable distance away, and which would not show within range of the lens. You get some idea of the difficulty when I make this comparison—if you estimate the volume of sound at a distance of one foot from the recorder at one hundred you find that at a distance of two feet it diminishes to twenty-five. The difficulty has now been overcome, although I expect to make my recorder much more effective than it is at present." [1]

In order more fully to appreciate the difficulty to which Edison thus referred, one may consider separately the two respective procedures of filming a motion-picture scene and of making a phonographic record. In the first case, the chief requirement with respect to the camera is that the scene should be within focus. Then the crank is turned and the "footage" is taken. Characters may speak their lines but the action, when projected, is pantomime; sound has no part in it. What the characters may say must be followed, if at all, by lip-reading only. In the second case, the chief requirement with respect to the recording apparatus is to get a satisfactory record of sound. It was long found impossible to obtain such a record if the sound were produced at more than a comparatively slight distance from the horn.

In the kinetophone, the motion-picture camera and the phonographic recording apparatus had to be combined. Action and sound were both essential. Characters must move about, speaking or singing; yet a satisfactory record must be made of what they said or sang. Hence, a special recorder had to be devised—a recorder sensitive enough to catch and register any sound-wave at a distance of forty feet, yet not visible in the picture. Edison

[1] I. F. Marcosson, "The Coming of the Talking Picture," in "Munsey's Magazine" for March, 1913; pp. 959–960.

evolved a recorder that made practicable the kinetophone.

Something further was, of course, needed—a synchronizing device; that is, a device by means of which action and sound could be *simultaneously* recorded and *simultaneously* reproduced. Neither could be allowed to run away from the other. Edison contrived an ingenious arrangement by which this synchronizing could be effected.

For the making of a talking motion-picture, the phonographic record set the pace; action was subordinate to sound. Beside the camera, and connected with it, was placed the sensitive recorder, to which was attached a receiving horn. When the camera-man started to turn the crank, the record and the film began together. It might happen that there would be no sound-wave to be registered until several feet of film had been ground out. This would be cared for by means of an automatic adjustment. The record was made on wax cylinders of the same general style as the record-blanks used with the regular cylinder type of phonograph. The picture negative was taken on standard celluloid film. From the wax originals were made the "indestructible" commercial records; from the film negatives were printed the positives employed in the projection-lantern.

When the talking motion-picture was produced, the projection-lantern at the rear of the auditorium was connected by wires with a phonograph placed out of sight behind the screen at the front of the auditorium. The operator of the projection-lantern could start or halt the phonograph without leaving his place; but the record while it was running really controlled him. That is, as has been said, it set the pace for the film. The statement was made that the operator could even turn his back while the picture was appearing on the screen.

In November, 1912, Edison remarked of the kinetophone: "It isn't exactly what I want it to be yet, but it will soon come as close to perfection as these inventions generally come, from my point of view, for I am never satisfied."[2] The introductory exhibitions of it were regarded by qualified observers as markedly successful. The material used included instrumental and vocal selections; "sketches" and tabloid comedies; dramatic fragments such as the scene between Brutus and Cassius in Act IV of "Julius Cæsar"; operatic bits such as extracts from "Il Trovatore"; part of the Planquette operetta "The Chimes of Normandy" ("Les Cloches de Corneville"). Kinetograph features were added for a time to the programmes of many better-class vaudeville houses. That a good talking picture would be superior to much of the usual vaudeville, there was no doubt. Edison mentioned the possibility of a synchronizing attachment that might be placed on the ordinary projection apparatus of motion-picture theaters. He said, however: "The talking motion picture will not supplant the regular silent motion picture. Each has its distinct use." He also appreciated the difficulties involved in preparing for the kinetophone more sustained material in full length.

The novelty soon passed of the use of the talking picture for popular amusement. Edison turned to other things. When peaceful development was resumed after the World War effort, radio-telephony quickly advanced as an engrossing new interest. In 1926, in a newspaper interview, Edison was reported to have given it as his opinion that the talking motion-picture would not be a commercial success in the United States because the

[2] Bailey Millard, "Pictures That Talk," in the "Technical World Magazine" for March, 1918.

American public preferred the "silent" film. The larger possibilities inherent in the talking picture when used for purposes of historical and scientific record, may, however, be said to be as yet untried.

In 1914 Edison announced the telescribe, on which he had been working since 1909, and the transophone, on which he had been working since 1912. The first was an extension of the use of the phonograph; the second a development of the office phonograph (dictating machine or "Ediphone").

As has earlier been pointed out,[3] a statement made by Edison in 1878 showed that he had even then considered the general notion of the telescribe. The general notion was to provide for making automatic records of telephone conversations. A phonograph had somehow to be connected with receiver and transmitter of an ordinary telephone outfit. Edison, setting out to accomplish this, encountered many technical hindrances.

The idea was finally realized in such a manner that the phonograph by which telephone talk was recorded could at other times be used as a regular dictating machine, and that no change was needed in the telephone equipment already installed. Separate from both the phonograph and the telephone was a metal box containing a highly sensitive transmitter; a dry battery to provide current for the extra circuit; and a pneumatic switch for controlling the phonograph. A person wishing to have a record made of a telephone conversation, removed from its hook the regular telephone receiver and inserted it, outer end down, in a spring-socket where it was held firmly in place upon a leather pad. The sensitive auxiliary transmitter in the metal box was thus automatically connected. The place of the regular tel-

[3] See Chapter IX, p. 98.

ephone receiver was taken by a handy substitute attached to the extra circuit. The phonograph had a special receiver that could be swung into position above the phonographic recorder but was not connected with it.

When once connection had been obtained on the telephone line and the record-cylinder had been released by means of the switch, a record could be made—not only of what was heard at the substitute receiver but also of what was spoken into the regular transmitter. The auxiliary transmitter in the metal box vibrated in unison with the diaphragm of the telephone receiver in the spring-socket, and the vibration was passed along to the special receiver adjusted over the phonographic recorder. The diaphragm of the recorder vibrated in its turn; and as the phonograph cylinder revolved, the cutting-tool incised a record-groove in the wax. A cylinder bearing such a record was called a "telescript," and could be filed away for reference, repetition, or transcript. By means of the switch, the record-cylinder could be halted and started again as desired. Thus certain portions of a conversation might be selected for record, and others omitted. The office phonograph used was of the current Edison type, but previous types could be adapted. It was evident that such a device might serve numerous useful purposes in many fields. Edison's study of electro-magnetic recorders in connection with his telescribe experiments was later to prove of service in the sound-ranging apparatus developed by him at the time of the World War.

The transophone was a mechanical improvement that Edison made in the control of the office phonograph. When the original office phonograph (dictating machine or "Ediphone") was subjected to everyday use, a lack was discovered. Typists might wish a small part of their material repeated—as, for example, when they had

failed to catch certain words. They found that such a partial repetition was impossible—the record would have to be started all over again. To remedy this defect, a lever arrangement was added. By means of the lever, the reproducing stylus could be set back to a desired point on the record. But to throw the lever, the typist had to turn from the typewriting-machine. Hence occurred a certain break in the typist's attention and a certain suspension of the immediate work. The consequent loss of time was objected to in a business world wherein "motion study" was a topic of the hour and the "efficiency" of clerical assistants was coming to be minutely examined. Furthermore, many typists, clinging to the shorthand note-book, were quite ready on general principles to find fault with dictating machines. Edison therefore developed the transophone. As in the case of the telescribe, many obstacles had to be overcome.

Close to the keyboard of the typewriting-machine was placed an electric switch having a button similar to a key of the machine. The typist depressed this supplementary key by a touch like that used for depressing one of the regular keys. On the phonograph was a magnet. When depressed, the button (or supplementary key) affected a quick-acting make-and-break (or interrupter) on the magnet circuit. The circuit was closed, the magnet was energized, and the armature of the magnet was attracted. Thus a cam attachment was moved and the travelling carriage was raised from the feed-screw and "back-spaced"—that is, moved back to a given point.

It was claimed that through the transophone the "efficiency" of a typist was increased by as much as twenty-five per cent. At the same time, the typist's own comfort and convenience were decidedly enhanced. The regular progress of the record was started or halted by

a foot-pedal. The transophone device was so made that with but little trouble it might be connected to any standard dictating machine.

In making records for his disc phonograph, Edison used a certain chemical. It was said that he used more of it than did any other manufacturer in the United States. The chemical was phenol. Phenol is carbolic acid (C_6H_5OH), and Edison used it in crystallized form. "It works beautifully," he said to a friend,[4] "and really it is indispensable."

The main commercial source of phenol was coal-tar—that portion of coal-tar that distils at between 150 and 200 degrees Centigrade. It had never been commercially profitable to extract phenol from American coal, so small was the fraction of phenol that American coal yielded. English and German coal was found satisfactory for the purpose; and for this reason the phenol used in the United States came from England and Germany. When the World War began, the supply of phenol from England and Germany was interrupted. It was interrupted because phenol was required for making picric acid (trinitrophenol); and picric acid was in demand in both England and Germany because it entered into the formulæ of high-power explosives.

Edison sounded American manufacturers of chemicals as to whether they would undertake the manufacture of synthetic phenol—that is, phenol prepared by uniting various elements into a compound. They reported that months would be needed—somewhere from six to nine—before they could furnish any. Edison didn't intend, if he could help it, to shut down his disc-record works. He

[4] W. P. Phillips, "Edison, Bogardus and Carbolic Acid," in the Electrical Review and Western Electrician" for November 14, 1914.

decided to make synthetic phenol. He studied the various known processes, selected the process he believed most suitable, and established a formula.

Three shifts of men were set at work to build a factory. On the eighteenth day after ground was broken, the factory was running and was turning out a thousand pounds of synthetic phenol a day. This output was sufficient to keep the disc works going, and a shut-down was averted. The phenol was purer than that derived from coal-tar; better, in fact, than was called for by the "United States Pharmacopœia." Within a month after it was started, the plant was capable of turning out a ton daily; and Edison disposed of surplus product to be converted into aspirin, salicylate of soda, salicylic acid, and salol. "Phenol is hard to make," he admitted, "but that's why I like to do it." . . .[5]

When Edison closed his ore-milling plant,[6] with its frame buildings, the insurance on it was cancelled by the insurance companies. According to Edison, they said, when he asked the reason: "Oh, this thing is a failure. The moral risk is too great." To which he replied that he was glad to hear it, and that he would thereafter build plants that had no such thing as a moral risk. Accordingly his cement mill at New Village was built of steel and concrete, with "not a wagon-load of timber" (as he said).[7] The later buildings at West Orange were constructed in the same way. At that time it was generally believed that structures of these combined materials were practically indestructible by fire. This belief had not, however, really been conclusively tested.

[5] "Edison's Gift to Humanity," in "The Literary Digest" for October 2, 1915.

[6] See Chapter XII, pp. 194–200.

[7] D. and M., II, 520.

On the night of December 9th, 1914, the West Orange establishment was partly destroyed by a fire that started in a film-inspection booth in a one-story frame building. Six buildings of wood or brick were burned, as were the contents of seven structures of reinforced concrete. Equipment was wrecked and quantities of supplies were consumed. Early on the morning of the 10th a force of men was at work clearing away the ruins, and during the day this force was greatly increased. The work was carried forward by night and day. Inside of thirty-six hours after the fire, Edison had issued orders for a full reconstruction of the plant. From a study of the fire's results, he felt that he had learned much about methods by which reinforced concrete might be made more truly fire-resisting. These effects were also studied by a committee of the American Concrete Institute, and the committee's detailed and illustrated report was undoubtedly of great value to architects, plant engineers, and others.[8]

From the midst of this fire a framed photograph of Edison was recovered. The heat had cracked the glass, the blaze had charred the frame, but the portrait had escaped. On the mount of the photograph, Edison lettered: NEVER TOUCHED ME!

On July 7th, 1915, Josephus Daniels, Secretary of the Navy, addressed to Edison a letter in which it was proposed that the inventor undertake "a very great service" to "the Navy and the country at large." The Secretary said that in his judgment an imperative need of the Navy was "machinery and facilities for utilizing the natural inventive genius of Americans," in order to "meet the new conditions of warfare as shown abroad." (It was evident

[8] This was printed originally in the "Journal" of the Institute, and was reprinted in pamphlet form (104 pp.; Philadelphia, 1915).

that he had especially in mind the submarine and the part it was playing in the World War, then in progress.) He therefore intended to establish "a department of invention and development," to which might be referred "all ideas and suggestions, either from the service or from civilian inventors." [9]

At the time of writing, he explained, inventions received from the public had to be turned over to various Navy bureaus "already overcrowded with routine work." Hence attention could not always be given to ideas and suggestions that might be worthy but were undeveloped. Naval officers on sea duty were in a position to note where certain improvements might be made, but had neither the time nor the special training "nor, in many cases, the natural inventive turn of mind" to put into definite shape such ideas as they might have. Then, too, the Navy Department lacked facilities for experimenting. Thus it was that the Secretary came to consider the idea of a board of specially selected men, to whom might be referred ideas and suggestions submitted to the Navy Department. Though means were at hand to make a start, yet eventually such a board would require Congressional appropriations, and therefore "Congress must be made to feel that the idea is supported by the people."

". . . I feel," continued the Secretary, "that our chances of getting the public interested and back of this project will be enormously increased if we can have, at the start, some man whose inventive genius is recognized by the whole world to assist us in consultation from time to time on matters of sufficient importance to bring to his attention. You are recognized by all of us as the man above all others who can turn dreams into realities and

[9] L. N. Scott, "Naval Consulting Board of the United States" (Washington, 1920). This is the official history of the Board.

who has at his command, in addition to his own wonderful mind, the finest facilities in the world for such work.

"What I want to ask is if you would be willing, as a service to your country, to act as an adviser to this board, to take such things as seem to you to be of value, but which we are not at present equipped to investigate, and to use your own magnificent facilities in such investigation if you feel it worth while. For our part we will endeavor not to bother you with trivial matters, as we will probably have sufficient facilities to handle such small matters as they come up. This is a great deal to ask, and I unfortunately have nothing but the thanks of the Navy, and I think of the country at large, together with the feeling of service to your country that you will have, to offer you by way of recompense."

The Secretary added that he relied chiefly upon Edison's aid, and hesitated, if that aid were not forthcoming, to undertake the matter at all. On July 13th, 1915, Dr. M. R. Hutchison, Edison's chief engineer and personal representative, called upon Secretary Daniels in Washington and informed him that Edison had consented to head a board such as the Secretary had proposed. The Secretary and Edison later had a conference at "Glenmont." Then the Secretary wrote to the presidents of eleven technical societies,[10] asking that each society choose two of its members to serve on the projected board. Dr. M. R. Hutchison was added by Secretary Daniels to the personnel. The organization meeting of the board was

[10] They were: American Aëronautical Society; American Chemical Society; American Electrochemical Society; American Institute of Electrical Engineers; American Institute of Mining Engineers; American Mathematical Society; American Society of Aëronautic Engineers; American Society of Civil Engineers; American Society of Mechanical Engineers; American Society of Mining Engineers; Inventors' Guild.

held on October 7th, 1915, at the Navy Department in Washington, and the official title "Naval Consulting Board of the United States" was adopted. Edison was elected the Board's first chairman, but subsequently William L. Saunders became chairman and Edison's official title was changed to "president." It was at the outset understood between Edison and Secretary Daniels that Edison was to act as adviser to the Board, not to give his time to executive and administrative duties. The Naval Consulting Board had at first no fixed status but was simply attached in an advisory capacity to the office of the Secretary of the Navy. On August 26th, 1916, it was legalized by Congress.

One of the first constructive tasks undertaken by the Board was an industrial inventory of the United States for the purpose of collecting data on the basis of which the manufacturing resources of the country might, in case of emergency, be organized to produce materials needed for use in war. In connection with this inventory, an "industrial preparedness campaign" was inaugurated to arouse the interest of the public in the subject of "preparedness." The inventory was accomplished in about five months.

On May 13th, 1916, a "citizens' preparedness parade" took place in New York City. Announcement had been made that Edison intended to march, and he had received letters threatening his life. Nevertheless, he appeared in line, and, with two secret-service men on each side of him, covered the entire route. With him walked the Naval Consulting Board, leading the engineers' section of the parade. All along the way, he was recognized and greeted with applause. (It was officially recorded that he "seemed to receive more applause than any other

marcher.") The newspapers carried pictures of him marching and referred to the influence exerted by his presence.

The Naval Consulting Board tendered its services to the Council of National Defense. This offer was accepted and the Board became one of the subordinate agencies of the Council, with the title of Board of Inventions.[11] The National Research Council acted as the science and research agency of the Council of National Defense.[12] The Naval Consulting Board thus came to serve as a board of inventions for both the Navy Department and the United States Government. From inventors throughout the United States, it received hundreds of suggestions and ideas a week—chiefly having to do with naval matters. Several members of the Board developed inventions of their own.

In January, 1917, Edison, at the request of Secretary Daniels, undertook the study of such plans and the development of such inventions as he deemed might be of use if the United States became involved in the war. He turned over his business affairs to others and abandoned the research and experiment in which he was then engaged. For two years he gave his attention entirely to this special work. In his laboratory workshops some fifty skilled mechanics were available for constructing experimental apparatus. On his staff were several young engineers who acted as technical assistants; and to these were added other technical men detailed from industrial establishments and volunteers from the universities and

[11] This arrangement dated from February 15, 1917. The Council of National Defense consisted of the secretaries of Agriculture, Commerce, the Interior, Labor, the Navy, and War.

[12] This connection dated from February 28, 1917. The National Research Council had been organized in April, 1916, at the request of the President of the United States, by the National Academy of Sciences.

colleges. Secretary Daniels afterward wrote [13] that Edison "practically became a naval officer, spending long months in the Navy Department and extended periods of deep-sea cruising that he might be in the closest touch with the problems to be solved." Edison's inventions were experimentally developed to a point where a definite report could be submitted to Army or Navy officials, to whom they were designed to furnish new ideas, provocative of further experiment.

It has sometimes been supposed that Edison had never previously been interested in inventions connected with warfare. This is a mistake. At the time of the Spanish-American War (1898), he suggested to the Navy Department the use of a shell containing a compound of calcium carbide and calcium phosphite, for making enemy ships visible at night. Such a shell would explode on striking the water, and the compound would take fire. The resulting flare could not be extinguished and would burn for several minutes, with an effective range of from four to five miles. Edison also aided W. Scott Sims in producing the Sims-Edison torpedo. This torpedo was hung from a float in such a way as to be held a few feet below the surface of the water. It contained, in addition to the explosive charge, a small electric motor that furnished driving and steering power. When fired, it trailed behind it an electric cable through which it could be controlled. The torpedo was found to be lacking in speed to such an extent that its practical value was seriously impaired, and before long it became obsolete.

Official acknowledgment has been made of thirty-nine inventions and plans communicated by Edison to the Washington authorities as a result of the work taken up at Secretary Daniels' request. These are:

[13] In his Preface to Scott's book.

Listening device for detecting submarines

Method for quick turning of ships

Strategic plans (with maps) for saving cargo boats from submarines

Collision mats

Plan for taking merchant ships out of mined harbors

Scheme for camouflaging cargo boats and burning anthracite coal

Plan for coast patrol by submarine buoys

Cartridge (or small depth bomb) for taking soundings

Sailing light for convoys

Plan for smudging sky-line

Plan for obstructing torpedoes by nets

Underwater searchlight

Oleum "cloud"-shell

High-speed signalling shutter for use with searchlight

Water-penetrating projectile

Method of observing periscopes in silhouette

Steamship decoy

Study of zigzagging by merchant ships in the danger zone

Device for reducing rolling of warships

Method of obtaining nitrogen from the air

Method of stabilizing submerged submarines

Hydrogen detector for submarines

Induction balance for submarine detection

Device for protecting observers from smokestack gas

Turbine head for projectiles

Scheme for mining Zeebrugge harbor

Mirror-reflection signal system

Device for lookout men

Oleum shell for blinding submarines

Method of extinguishing fires in coal-bunkers

Device for "finding" enemy airplanes
Apparatus for sound-ranging
Telephone system for ships
Extension ladder for "spotting-top"
Reacting shell
Night glass
Oil for smudging periscopes
Attachment for keeping range-finders free of spray
Means for preserving submarine and other guns from rust

It will be noted that these items have very largely to do with naval equipment and affairs. Only a few of them can here be described, and they in but the briefest fashion. The twelve selected have been chosen on no particular basis, but may perhaps be regarded as representative in that they serve to indicate how extensively Edison was occupied with the question of defence against submarines.[14]

Listening Device for Detecting Submarines.—This took the form of an outrigger to be suspended from the bow of a merchant ship. The listening device proper was about twenty feet long and sixteen inches wide, with a brass body containing tubes of brass and a phonograph diaphragm at the end that hung in the water. By means of a worm worked by an electric motor, bowsprit and arm could be swung toward the ship and the listening device could thus be landed on deck, so that necessary repairs could conveniently be made. A compensating arrangement "cancelled out" the noise of the ship's engines; and by aid of an adjustment, confusing noises made by other boats could likewise be excluded.

Even in the roughest seas, with a ship going full speed (in that case, fourteen knots), this device resisted injury.

[14] Scott's volume has here been used as chief authority.

While the ship was proceeding at full speed ahead, other boats could be heard at a distance of 1,700 yards and a submarine bell could be heard at a distance of five and one-half miles in the midst of a heavy storm. It was stated that with this contrivance, a torpedo—"the noisiest craft that sails the sea"—could readily be heard at a distance of over 4,000 yards.

Method for Quick Turning of Ships.—This was to be used in connection with the listening device. By this means, if the noise of a torpedo had been heard, a merchant ship could quickly change to a course at a right angle to its previous course and thus avoid the torpedo. Four sea-anchors were used. A sea-anchor is a stout canvas bag of conical shape, with a small rope attached to the little end and a heavy rope fastened to the mouth end. This heavy rope is made fast to the ship. Such an anchor is ordinarily used for arresting the speed of a vessel. It is thrown into the sea and, filling with water, acts as a drag. Tension on the small rope opens the little end of the bag by means of a slip-noose.

The four sea-anchors used by Edison were each nine feet in diameter at the mouth end and hitched to a four-inch rope. The ropes were firmly attached to the bow and the anchors were placed amidships. If the listening device detected a torpedo, the anchors were to be cast overboard and the helm at the same time thrown hard over. This method was tried successfully with small boats and also with the 5,000-ton U. S. S. "Clio," loaded with 4,200 tons of coal. The "Clio" in two minutes and ten seconds was turned ninety degrees from her original course, with an advance of only 200 feet.

Collision Mats.—These were intended to reduce losses of shipping from damage by torpedoes. One of the mats was to be launched in such a way as to cover the opening

made by a torpedo explosion. Each mat was forty feet long and thirty-five feet wide, and was rolled on a six-inch pipe. The time required for launching was only fifteen seconds.

Cartridge (or Small Depth Bomb) for Taking Soundings.—This was a bomb about the size of the ordinary shotgun cartridge (shell) and could be produced at comparatively low cost. It was designed for use by vessels equipped with the listening device already mentioned, and was for "safety signalling" in fogs and for finding out whether or not a safe depth of water was under a boat. Two types were devised—one to explode on touching bottom, the other to explode at a given depth for which it had been set. In the first instance, the elapsed time between the firing of the bomb and its explosion would indicate (with the aid of a carefully prepared time-table) the depth of water.

Sailing Light for Convoys.—This was evolved to meet the demand for a light that should not be visible from the deck of an enemy submarine at the surface of the water. It consisted of several discs painted dead black and each approximately eighteen inches in diameter. The discs were about a thirty-second of an inch apart, and a six-candlepower incandescent electric lamp was so placed as to shine between them. A gyroscope run by a small electric motor kept the whole device constantly horizontal and thus independent of the motion of the vessel at a given time. In this manner the light-rays remained parallel; and hence, though invisible from the periscope or deck of an enemy submarine, they were visible to an observer in the crow's-nest of another vessel of the convoy.

Underwater Searchlight.—A long series of experiments was conducted in the attempt to provide a searchlight for underwater use by submarines. Arc lamps were em-

ployed in connection with tubes filled with water. Carbons bearing various elementary substances were tried for the arcs, and the green lines in the spectrum of barium were found more effective in penetrating salt water than was any other sort of ray noted in the tests. With these lines, sufficient light was transmitted through a sixty-foot tube filled with sea water to permit print to be read.

Oleum "Cloud"-shells.—Experiments were made with a shell that, on bursting, would yield a dense cloud of suffocating white vapor that could be particularly used to interfere with the view from enemy ships. This shell was in a general way constructed similarly to shrapnel shells except that the shrapnel was replaced by a can of smoke-producing compound.

High-speed Signalling Shutter for Use with Searchlight.—This consisted of a Venetian-blind arrangement set in a frame; and, connected to this shutter, an electro-magnet in circuit with a telegraph key. The key controlled the electro-magnet, and the electro-magnet caused the shutter either to open or to close. In this way, signals could be flashed with the Morse alphabet. A speed of forty words a minute was attained.

Steamship Decoy.—This was another device intended to aid in protecting merchant vessels against submarines. It was a water-tight drum of thin sheet-iron, divided into compartments for holding a smoke-producing material and provided with a funnel. When the material had been ignited and the drum set adrift, the smoke would appear like that from a distant steamer and thus mislead the commander of a submarine.

Hydrogen Detector for Submarines.—A reliable instrument was needed for detecting the presence of an excess of hydrogen gas and thus preventing explosions. Edison made one that was accurate, simple, and so sensitive as

to be capable of indicating the presence of three one-hundredths of one per cent. of hydrogen gas in a submarine's atmosphere.

Telephone System for Ships.—This was a distinct improvement over systems in use at the time. Edison discarded microphone transmitters and used the receiving apparatus as a transmitter. By means of an audion, he greatly increased the strength of signals. An improved earpiece was also developed.

Method of Extinguishing Fires in Coal-Bunkers.—In seeking means for extinguishing fires in the coal-bunkers of naval vessels, Edison found sodium silicate (commonly known as "soluble glass" or "water glass") to be markedly effective. If a stream of the sodium silicate were played upon a fire, the relatively small quantity of water in the silicate was evaporated and the incandescent material was blanketed with a glassy coating. This coating excluded oxygen and the fire was thus extinguished. The sodium silicate could be cheaply manufactured.

In certain of this war work, Edison was able to turn earlier researches to account. For example, long study of the phonograph was of aid in his experiments with a listening device; experience in telegraphy and in telephony was utilized in connection, respectively, with the high-speed signaling shutter and with the telephone system for ships; and knowledge gained in developing the telescribe assisted in the perfecting of the apparatus for sound-ranging, which employed phonographic records made with electro-magnetic recorders. Edison, having heard it was said that the Germans were manufacturing nitric acid from ammonia, set up apparatus that he had used when he was engaged with the problem of the nickel-iron storage battery. At that time, while experimenting with the reducing of iron by hydrogen, he had passed

hydrogen and nitrogen over the reduced (*i. e.*, finely divided) iron in order to render it non-pyrophorous,[14] and ammonia had been produced to a considerable extent. He now discovered that the reduced iron, if lampblack were mixed with it, would yield large quantities of ammonia. The ammonia could then be absorbed in acid.

Here and there in Scott's history one encounters hints of difficulties in the course of these experiments for the Government—experiments whose full results could be attained only through the medium of existing departmental bureaus, with their more or less strictly defined duties and inflexible routine. For instance, when Edison was working on a sailing light for convoys, an electrician from a United States submarine was detailed to assist him; but before a perfected model had been completed, this electrician was permanently withdrawn.[15] When details of Edison's hydrogen detector had been submitted, service experts declared the instrument "too fragile." Yet Edison later had one of the detectors placed on a submarine constantly used in maneuver practice, and at the end of nine months (at which time it was removed) it was found to be "all right." When Edison was making trials of his schemes for a listening device, various small steamers were placed at his disposal. "Unfortunately," comments Scott, "the respective vessels were not in the best of condition and were laid up for repairs at frequent intervals." . . .[16] Finally, before the experiments had been finished, the latest ship detailed was withdrawn—"which, of course, put an end to the work."

14 Some metals, of which iron is one, will, when finely divided and exposed to the air, combine so rapidly with oxygen that light and heat result. Such metals are said to be "pyrophorous" or "pyrophoric."

15 Preliminary tests in Chesapeake Bay had already shown the principle to be a correct one.

16 P. 163.

Edison submitted ideas about a turbine head for projectiles (so that eroded and smooth-bore guns might be used), and ordnance experts said the turbine-head projectile would tumble (*i. e.*, turn end over end) when fired from a smooth-bore gun. Tests later made by Edison with an old smooth-bore one-pounder showed that the turbine-head projectile did not tumble but regular projectiles tumbled badly. While preparing strategic maps to suggest graphically how, in case enemy submarines appeared near the eastern coast of the United States, trans-Atlantic and coastwise shipping might best be managed, Edison discovered that no bureau had any statistics of the sailings of coastwise ships to and from the various harbors.

In 1923, on the occasion of his usual birthday conference with newspaper men, Edison was quoted as saying: "I made about forty-five inventions during the war, all perfectly good ones, and they pigeon-holed every one of them. The naval officer resents any interference by civilians. Those fellows are a close corporation." . . .[17] No official statement, either of a general sort or directly bearing on these remarks, was forthcoming from the Navy Department, but news dispatches from Washington reported that individual naval officers mildly disallowed any unfriendly attitude on their part toward civilian inventors.[18]

[17] See "The World" (New York) for February 13; the "New York Tribune" of the same date. The interview was on February 12, the 11th having fallen on a Sunday.

[18] *Ib.*

XV

MISCELLANEOUS ACHIEVEMENTS

One day when he was not far past sixty, Edison, in talking with a friend, fell to reviewing earlier inventions. After a time, with an air of having but just made an amusing discovery, he smiled expansively and observed, "Say, I *have* been mixed up in a whole lot of things, haven't I?" [1]

This may be regarded as a fair and modest inference if one considers that from June 1st, 1869, when a patent was granted on his automatic vote-recorder, to about the middle of 1910, he applied for 1,328 distinct patents—roughly one for every eleven days of the entire period. It had with reason been said of him that he kept the path to the Patent Office hot with his footsteps. Moreover, his inventive work is not fully represented by the number of patents applied for, since certain inventions were kept as "trade secrets," no attempt being made to patent them, and others were left unpatented and given to the public. Then, too, from one cause or another, many ideas had been left undeveloped, many researches had been abandoned.

One of the things Edison had been "mixed up in" was the electric railway. Americans had already made ingenious pioneer experiments in electric traction. Thomas Davenport, a Yankee blacksmith and mechanic of Brandon, Vermont, was the earliest. Moses G. Farmer (William Wallace's technical assistant in arc-lighting) ex-

[1] D. and M., II, 705.

hibited through New England a model of an electric locomotive. Prof. C. G. Page built an electric motor that on April 29th, 1851, made a trip over the Baltimore and Ohio from Washington to Bladensburg, Maryland, and reached a maximum speed of nineteen miles an hour. Only about twenty years before that—in 1830—had Peter Cooper's steam locomotive run from Baltimore to Ellicott's Mills and back over a railway that later became part of the Baltimore and Ohio system. Page's motor carried a hundred Grove cells to supply current. All these primitive ventures depended on chemical batteries. That is why their possibilities were limited. Only with the appearance of the dynamo was a basis found for true progress.

In the spring of 1880, busied though he was in perfecting the details of his central-station electric system, Edison managed to discover some spare time, and he utilized it by taking a fling at the electric railway. At the rear of the laboratory inclosure at Menlo Park, he had a track laid—an ungraded track, put together with old street-car rails and makeshift insulating material. It made a loop of about a third of a mile, swinging around a little hill and affording some risky curves. The gauge was approximately three feet and six inches.

Current was furnished by two Edison lighting dynamos of what was known as the Z type—colloquially styled "long-waisted Mary Anns." These were rated at not far from twelve horsepower each. Like other Edison dynamos, they had low internal resistance and a high-resistance field. The current was conveyed underground, Edison being no friend of overhead wires. The locomotive was a compeer of the track. On an ordinary little four-wheeled dump-car was mounted a third "Mary Ann," laid on its side and with its armature end at the forward end of the

car. The current received from one rail by the wheels on that side, was carried to the dynamo, which was used as a motor. In like manner the circuit was completed through the opposite wheels to the other rail. The motor was therefore said to be "in parallel" or "in multiple arc." Power was at first transmitted to the driving-axle through a troublesome arrangement of friction pulleys. Should the motorman wish to reverse the locomotive, he worked a switch and shifted the flow of current through the armature-coils.[2]

This machine had its initial trial on May 13th, 1880. Everybody around the laboratory tried to crowd on board for a ride. The friction-pulley system promptly broke down and was immediately discarded. Then belts were tried—one from the armature to a countershaft, another from the countershaft to the axle. After the motor had been started, the belt from countershaft to axle was drawn taut by means of an idler pulley, and thus the locomotive got under way. This method wasn't much better than the friction pulleys had been. If the axle-belt were too abruptly tightened, the armature was burned. "The odor of burnt armature," wrote T. C. Martin, "was grimly familiar during the tests." The belts would char if they slipped much—and they slipped continually.

Then Edison put resistance-boxes in the armature circuit. All over that crude locomotive he fastened resistance-boxes. The resistances were successively "cut out" as the locomotive was gradually brought up to maximum speed. Believing that he could very well do without the extra load of those numerous boxes, Edison wound copper resistance-wire around a leg of the field-magnet of

[2] T. C. Martin, "Edison's Pioneer Electric Railway Work," in the "Scientific American" for November 18, 1911.

the motor. In series with the armature, this coil could be put into circuit by a plug-key and cut out of circuit by the same means. Thus gradually was solved the particular problem of how to apply the motive power. This instance of development indicates how much in this field had then to be learned by experience.

New rolling-stock was added—an open flat car; a similar car with an awning over it and two benches for seats; and an inclosed affair referred to as "the Pullman." The track was extended to about a mile. The Menlo Park line was "written up"; celebrities, near-celebrities, and non-celebrities came to behold and ride. Surely no "Puffing Billy" or "Tom Thumb" of early steam-railway days, drawing its little coach-wagons, could have made a more fantastic picture than did Edison's first electric train jolting through the back-lots at Menlo! The locomotive would do as high as forty miles an hour, and sometimes the train would jump the track, but no casualties were recorded.

Railway officials and engineers were indifferent or incredulous. They were not quite so rude as "Commodore" Vanderbilt was when he dismissed George Westinghouse and Westinghouse's air-brake with the remark that he had no time to waste on fools. They were not quite so amused as Gardiner Hubbard was when he met Bell's utterances about the telephone with "Now you are talking nonsense." But in their general attitude they resembled one or the other or both. President Frank Thomson of the Pennsylvania was one day a passenger. Edison wished to have him install an experimental line covering the seven miles between Rahway and Perth Amboy; tried to interest him in plans for an electric locomotive having six-foot drivers and capable of developing three hundred horsepower. Thomson was more than sceptical.

He argued that the thing was not feasible. Also, he knew that nothing ever could or would replace steam. Edison has since admitted, ". . . I thought he might perhaps be mistaken." . . .[3]

One "practical" man who was big enough to appreciate the possibilities in Edison's ideas, was the journalist and financier Henry Villard, who, as a director of the Edison Electric Light company, had such strong confidence in the value of Edison's incandescent system. Villard, in his "Memoirs," wrote:[4] ". . . Mr. Villard was a firm believer from the outset in the availability of electricity as a motive power for transportation. . . . He was also convinced that the certain progress in the art of using the electric current for power and traction purposes would, sooner or later, lead to its substitution for steam even in factories and on standard railroads." . . . In September, 1881, Edison and Villard entered into an agreement by which Villard undertook to finance experiments and Edison was to build two electric locomotives—one for freight, capacity to be ten tons; the other for passenger service, speed developed to be sixty miles an hour. It was understood that if the trials proved successful, Villard would seek to enlist the aid of the Edison Electric Light company for the building of not less than fifty miles of electric railway in the wheat country of the West. Villard was at that time president of the Northern Pacific, and his plan was to inaugurate in this way a series of "feeders," over which wheat could be hauled to points on his road.

The original Menlo track was extended to about three miles; construction was improved, and the line rejoiced in a car-barn, two turn-tables, and three sidings. Duly

[3] D. and M., I, 459.

[4] See Vol. II, chapter viii, pp. 325–327.

built, the two new locomotives were conventionally equipped with pilot, headlight, and cab. The passenger locomotive hauled as many as ninety passengers at one time. The trials were successful but had no direct results, for the Northern Pacific fell into difficulties and passed for the time being from Villard's control. Nothing could persuade the Edison Electric Light company to manifest concern as to the "feeder" project. Villard had furnished something over $35,000 for expenses, and this sum Edison personally repaid.

Later, when Villard was again connected with the Northern Pacific and Edison was at West Orange, Villard thought the "mountain division" might be electrified. He consulted Edison on the matter and Edison devised the "third-rail" system. Villard's engineers assured him that anything of the sort was quite impossible. Evidently he was no more thoroughly convinced than was Edison. He said in his "Memoirs": ". . . As early as January, 1892, he [*i. e.*, Villard] convened a conference of electrical and railroad experts in New York to consider the problem of operating the Northern Pacific terminal lines in Chicago, as well as some of the branches of the main line, by electricity. The practicability of this at that time was negatived, but the growth of electric traction in the meantime has certainly rather confirmed than gainsaid his theory of the ulterior [ultimate?] prevalence of current over steam." . . .

In 1883 the Electric Railway company of America was formed in order to consolidate the interests of Edison and of Stephen D. Field. Edison was appointed consulting electrician, but active technical work was left to Field. A good start was made, but the business affairs of the company were poorly managed, internal differences cropped up, and in 1890 all rights to Edison patents were

assigned to the Edison General Electric company, organized by Villard in 1889. In 1896 the railway company was turned over to a receiver. The receiver sold Field's patents back to Field, who sold them to the Westinghouse company. Thus, through no apparent fault of either Field or Edison, their labors missed direct fulfilment. The art to whose beginnings they had lent such impetus, was carried forward by C. J. Van de Poele, Leo Daft, Frank J. Sprague, and others.

How fallible "practical" infallibility may be is indicated by certain later developments. Frank Thomson's road electrified its terminal in New York; so did the New York Central system. The Manhattan Elevated, which had once rejected the electric method Edison specially planned for it, subsequently adopted electricity, as did other elevated roads. Electricity was used from the first in the New York subways. Electric zones were introduced on the New York Central and New Haven lines. Or if one wished to go further afield from Menlo Park and West Orange, he might mention that in time the Illinois Central electrified its lines in and about Chicago, or that both the Chicago, Milwaukee and St. Paul and the Great Northern electrified their "mountain divisions." It is hardly necessary to adduce further instances to show that, after all, Edison and Villard were right. Rescued from oblivion at Menlo, Edison's first electric locomotive was placed in safe-keeping at Pratt Institute in Brooklyn, New York.

Flying was another thing that Edison was "mixed up in." He didn't fly. He built a helicopter. The helicopter didn't fly, either. The present airplane was developed from the glider. A helicopter is a flying-machine designed not to take the air by gliding but to rise verti-

cally from the ground. In 1923, in his regular birthday interview, Edison said: [5]

"I see the helicopter is coming on. I always did believe in that. Thirty-eight years ago James Gordon Bennett gave me $1,000 to make experiments in the direction of flying. I constructed a helicopter, but I couldn't get it light enough. I used stock ticker paper made into gun cotton and fed the paper into the cylinder of the engine and exploded it with a spark.

"I got good results, but I burned one of my men pretty badly and burned some of my own hair off and didn't get much further. But I knew then it was only a matter of experimenting, and I reported to Mr. Bennett that when an engine could be made that would only weigh three or four pounds to the horse-power the helicopter would be a success. I believed it to be the best method and the most likely to be successful. I haven't changed my mind, but I have had to wait a long while."

It is a mistake to suppose that radio is the only known sort of wireless electrical signalling. Radio is, as a matter of fact, but one variety of "wireless"—the sort that uses electro-magnetic waves. More than a half-century before Marconi started radio on its career as an art, S. F. B. Morse was sending "wireless" messages across a canal in Washington by means of electric conduction through the water. After that, others experimented more or less successfully with either conduction or induction. Edison (with the aid of Ezra T. Gilliland) worked out a very satisfactory "wireless" system of train telegraphy, based on what has been called electrostatic induction.

This system was tried experimentally on the Staten

[5] "The World" (New York), February 13, 1923.

Island railroad, and in 1887 was put into use on the Lehigh Valley. It was commonly styled the "grasshopper telegraph." A special telegraph wire, on poles shorter than the usual kind, was strung along the railway line.[6] One end of the system was in signalling-stations at various points on the route, the other in passing railway cars. Metal strips were laid on the roofs of cars so used, and these strips were connected with a telegraph outfit in which the standard apparatus had been modified by the addition of a "buzzer" and a telephone receiver. A signalling-station had a similar outfit. In sending, the "buzzer" was kept vibrating, and the operator by means of his key broke the vibration into the "shorts" and "longs" of the Morse code. These were transmitted by induction from the telegraph wire to the car or from car to wire—a distance of not to exceed fifty feet. The telephone receiver made the received signals distinctly audible. The system continued in use on the Lehigh Valley for some little time. Edison is authority for the statement that the patents were sold to a capitalist who declined to answer letters and refused to sell any rights.

But Edison took another step in the general direction of radio. He found that telegraph signalling by induction could be made effective at a much greater distance than that which sufficed for train telegraphy. His idea was to employ metal plates or other suitable "condensing surfaces" placed high above land or water. Such a surface was grounded through the secondary circuit of a high-voltage induction coil. The sending contrivance consisted of a circuit-breaker that was revolved by a motor and was kept short-circuited by a key except when signals were sent. For sending, the key was depressed; impulses were set up in the primary circuit of the coil;

[6] Some accounts say that the regular telegraph wires were employed.

and the secondary circuit in turn produced corresponding variations in electric stress at the "condensing surface." These variations would be intense enough to produce electromotive force that would reach to the complemental plate at the receiving station. For receiving, the electro-motograph, Edison's "loud-speaking telephone," was employed. The induced currents would cause the signals to be declaimed by the telephone. Edison thought this arrangement especially well adapted to use between vessels on the high seas, or between coast stations and vessels in-shore. Though he did not develop it, it has historical interest.

Curiously enough, he had chanced, several years before, upon the real key to radio. But he and his associates, after about a month of experiment, passed on to other things without having recognized the true significance of what they had observed; and afterward, when he was studying the matter of telegraphy without wires, he did not think of applying the "etheric force" that he had noted. "Etheric force" or "etheric current" was what he styled the cause of the phenomena witnessed at Newark in 1875.

It seems that while experimenting with a steel bar suspended near one of its ends and made to vibrate through the action of a magnet, he was forcibly impressed by the sight of sparks issuing from the cores of the magnet. The better to watch these sparks, he had a "dark box" made. Inside the box were two carbon points that could be adjusted by micrometer screws. When the "dark box" was placed in circuit with the vibrating device, the sparks between the carbon points could be watched through an eye-piece. Many experiments were tried, including some with that "good familiar creature" the frog, which from the days of Galvani has been so freely

called upon to perform for man's benefit. Great was the surprise at the fact that when a frog was placed in circuit with the sounder (or vibrating device) and the "dark box," although sparks at the carbon points were decidedly bright, no muscular movement occurred in the frog. Charles Batchelor took the "dark box" to the international electrical exposition at Paris in 1881,[7] and the phenomena were there shown in connection with the Edison exhibit.

It was Heinrich Hertz who explained the puzzle by producing and detecting electro-magnetic waves, sometimes called "Hertzian waves." He likewise pointed out the similarity of these to the waves of heat and light. That Hertz had derived anything from Edison's work is not at all likely. As a matter of fact, Clerk Maxwell had, as far back as 1867, "outlined theoretically the exact type of electro-magnetic wave that is used in radio to-day." The correctness of Maxwell's theory was established by Hertz.[8]

Had Edison continued his studies either in his "etheric force" or in space telegraphy, it is possible that he might have crossed the gap that lay between him and radiotelegraphy. As to this, one may merely speculate. In 1889 Lord Kelvin said:[9] ". . . Edison seems to have noticed something of the kind [*i. e.*, "Hertz sparks"] in what he called the etheric force. His name 'etheric' may, thirteen years ago, have seemed to many people absurd. But now we are all beginning to call these inductive phenomena 'etheric.'" It does not appear that Edison's

[7] See Chapter XI, pp. 157-158.

[8] See J. V. L. Hogan, "The Outline of Radio" (Boston, 1923; in the Useful Knowledge Books series, edited by G. S. Bryan), p. 10.

[9] In remarks before a meeting of the Institution of Electrical Engineers in London on May 16.

plan for elevated plates was ever practically developed. He has not claimed that he used the aërial wire (antenna), spark-gap, or high-frequency electro-magnetic waves on which Marconi founded radio. It has been stated [10] that in 1903, at a time when another company was bidding for them, he disposed of the patent-rights in his idea to Marconi's company because he thought that in the hands of rival interests they might possibly be used to make trouble for Marconi, of whose work he held a high opinion.

It should be added that when constructing and studying incandescent lamps he noted a phenomenon associated with the fact that incandescent bodies give out electrons. Scientists termed this phenomenon the "Edison effect." It helped to make radio history. Prof. J. A. Fleming of England in 1904 used a modified form of incandescent lamp as a radio detector; and thence was evolved the vacuum tube or audion that, for detecting, amplifying, and transmitting, came to be so extensively a part of radio apparatus.[11]

Edison was also "mixed up in" house-building. It was a peculiar sort of house-building, because it proceeded downward from above instead of upward from below. It produced a new sort of house—a house in one piece instead of many parts—a poured house.

The general idea of it seems to have occurred to Edison after he had entered on the manufacture of Portland cement. Portland cement was mixed with sand and coarse "aggregate" to make concrete. Various things were molded of concrete. Why not a house? "A decent house of six rooms, as far as the shell would go," he once said, "might cost only three hundred dollars or so. It would be

[10] D. and M., II, 380.

[11] See Hogan, "The Outline of Radio," pp. 16–17.

stereotypy over again and the expense for the models [molds?] would disappear in the duplications repeated all over the country."[12]

Later, he started to experiment. He found that his notions as to costs would have to be revised; also that such a house could not, as he had presupposed, "be poured in three hours, and be dry enough for occupancy in three days."[13] The process was, however, gradually reduced to a practical basis.

It was proposed to build the houses in large numbers in some particular locality—say, in an industrial suburb or the like. This was because only by group construction could costs so be kept down as to make the scheme of advantage to those whom he specially wished to benefit. The mold or form was to consist of a double set of sectional cast-iron plates, each smooth on the inside—nickel-plating or brass facing being employed for any relatively elaborate detail. Monolithic cellar walls, known as "footing," were to be prepared to receive the mold, which was to be set up by electric derricks. The mold-plates—hundreds of them, all told—were pinned and bolted together. Reinforcing rods were specified for roof, floors, or other spots where they might be needed. In the form, before the concrete was poured, were set the plumbing; pipes for gas, water, and heat; and conduits for electric wires.[14]

The mixture was 1:3:5—that is, one barrel of packed Portland cement to three barrels of loose sand and five of gravel or broken stone. These materials were supplemented by a colloid substance—that is, a jelly-like or

[12] George Iles, "Inventors at Work" (New York, 1906), p. 433.

[13] *Ib.*

[14] E. S. Larned, "The Edison Concrete House," in the "Scientific American Supplement" (1685; April 18, 1908). This originally appeared in the "Cement Age." It was reprinted by the "Scientific American" as a pamphlet, now out of print.

glue-like substance—intended to render the flow uniform when the concrete was poured and to help keep the heavier parts of the mixture suspended. Gravel was to be obtained, if possible, on the site. From mechanical mixers the mixture was dumped into a storage hopper, and from this it was taken by a bucket elevator to a distributing hopper at the top of the house. Pipes conveyed it thence to the molds. A three-story house could be poured in about six hours, and the concrete would harden in as many days.

When the concrete had hardened and the mold-plates had been removed, a house was disclosed of which not only stairways and interior walls but bath-tubs, laundry tubs, mantels, even picture-moldings, were integral parts. Then a heating apparatus could be put in; heating and plumbing connections made; doors, windows, and lighting fixtures added. The outside walls could be specially painted or tinted; the interior walls also could be tinted.

In order to obtain variety, six different molds would be used in an outfit and the molds would be so made that parts might be interchanged to form yet other arrangements. It was claimed that two houses a month could be turned out with one mold, or twelve with the set of six.

Civil engineers and experts in concrete had a host of objections to raise when Edison's tentative plans were first announced. They said that no mixture could be made to flow freely; that a mixture might flow freely through the vertical members of the mold but not in the horizontal members; that the surface would be imperfect; that the heavier parts of the mixture would sink and hence the mixture would not be uniformly deposited; that a colloid would retard the hardening of the concrete. All this they said, and a good deal more. By 1910, however, Edison was ready for a statement that difficulties had

been overcome and that the poured house had been definitely realized. He did not purpose to utilize the invention in projects of his own, but, subject to certain reasonable restrictions, with no return to him save for expense involved, it could be put into practice by others.[15]

One of the items often encountered in a list of Edison's inventions, is the electric pen. This was used to make stencils for manifolding manuscripts and was superseded by the mimeograph.[16] It obtained current from a small battery to which it was attached. Inside the pen-barrel were solenoid coils—coils of conducting wire wound in the form of cylinders. Inside the coils was a steel shaft or plunger at whose lower end was a stylus. When the battery current was on, the coils became solenoidal magnets; and the alternate attraction and repulsion set up between them and the plunger resulted in the motion of the stylus. As the pen was pushed along, the stylus made fine perforations in a sheet of special paper and thus a stencil was formed.

Among other inventions of Edison's in the electrical field is his "dead-beat" galvanometer. The common type of galvanometer used for measuring the strength of electric current, has both a coil and a magnetic needle. A current flowing in the coil around the needle, causes the

[15] In October, 1923, it was stated in newspaper dispatches that on a 5,000-acre tract south of the Dearborn plant of the Ford Motor company, Henry Ford would erect (if that is the word) 30,000 poured houses with molds that would permit of twelve different types! The houses would be sold, it was said, at a price close to the cost. Early in 1925 the writer learned from an authoritative source in Dearborn that this scheme had "not developed into a definite plan," and that it was doubtful whether it would be developed "for some time to come." The dispatches, it was added, "contained more imaginary statements than facts."

[16] See Chapter VIII, p. 71.

needle to be deflected. The amount of deflection is measured on a scale. A "dead-beat" or aperiodic galvanometer is one in which the moving needle comes quickly to rest, without swinging to and fro. Edison's galvanometer had neither coils nor needle. Instead, it depended on a bit of platinum-iridium wire shut in a glass tube. The current made the wire expand, and this expansion permitted a coiled spring to move a pivoted shaft. On the shaft was mounted a small mirror; and as the shaft moved, the mirror threw a shifting beam of light along a scale.

Passing mention may also be made of the Edison-Lalande primary battery, the manufacture of which became one of the Edison enterprises. This battery was found to be particularly reliable for use in connection with railway signals. The claim was made for it that it would function without polarizing—*i. e.*, that hydrogen gas would not collect on the surface of the negative element and thus decrease the current-flow by increasing the resistance.

Then, too, Edison was "mixed up in" the Roentgen rays—the "X-rays," as their discoverer, Prof. W. K. Roentgen, styled them because he was uncertain of their nature and hence applied to them the symbol of the "unknown quantity." Roentgen's discovery was made in 1895. Not long after the announcement, Edison set assistants at producing crystals of various chemical combinations. They thus assembled something like 8,000 different crystals. Edison was looking for substances that would fluoresce—*i. e.*, become luminous—under the action of the X-rays. This canvass yielded about 1,800 substances that would do so. From these he chose tungstate of calcium as the best.

He first made a fluorescent lamp—a glass bulb coated

on the inside with the tungstate. If an adequate vacuum were provided, the tungstate would, under the action of the X-rays, become luminous and the bulb serve as a lamp. He also invented a fluoroscope—an apparatus through which the effect of X-rays could be observed. This was a box flaring toward its outer end, where a fluorescent screen, coated on the inside with tungstate of calcium, might be attached. At the other end was an eye-piece similar to the eye-piece of a stereoscope; and the whole contrivance was held, when in use, by a handle like that of a stereoscope. If an object were interposed between the screen and the source of the X-rays, a "shadow" would be thrown on the screen. A very early public display—perhaps the first in the United States—of X-ray action, was that afforded when an Edison fluoroscope was shown at an electrical exhibition in New York City in 1896. The fluoroscope principle was applied with much success to surgical purposes.

That other purposes for it were entertained in artful but uninformed quarters, is indicated by the printed text of a letter said actually to have been received at the West Orange laboratory: "Dear Sir,—I write you to know if you can make me an X-ray apparatus for playing against faro bank? I would like to have it so I can wear it on my body, and have it attached to spectacles or goggles so I can tell the second card of a deck of playing cards turned face up. If you will make it for me let me know what it will cost. If I make a success out of it I will pay you five thousand dollars extra in one year. Please keep this to yourself. If you cannot make it will you be kind enough to give me Professor Roentgen's address? Please let me hear from you."

The odoroscope (or odorscope) was an ingenious af-

fair that, like the tasimeter (or microtasimeter),[17] made use of the fact that as pressure on carbon is increased, the electrical resistance of the carbon is decreased. It was constructed similarly to the tasimeter. The tasimeter had a strip of vulcanite, a platinum plate, a carbon button, and another platinum plate. The odorscope had a strip of gelatine in place of the vulcanite. It not only was influenced by heat but also was so readily affected by moisture that a few drops of perfume or of water thrown on the floor of the room in which it was would be at once detected by the instrument. In circuit with the carbon button and the two platinum plates were a battery and a galvanometer; and the galvanometer forthwith responded. This invention could be used for testing gases. It could also be adapted to hygrometers or barometers.

Far more familiar is the megaphone, though not in its original form. As Edison first planned it, a megaphone had two funnel-shaped wooden or metal horns set on a tripod at a fixed angle to each other. Between these was a speaking-trumpet. From the small ends of the horns ran flexible ear-tubes. With the aid of this device, a person could hear and be heard over a distance of more than two miles. What is generally known to-day as a megaphone, is a funnel of papier-mâché, shaped like one of the receivers of the original megaphone but used as a transmitter. It finds employment in many ways—by yachtsmen, cheer-leaders, coxswains, motion-picture directors, announcers, guides. It even wings from the back porch the summons to meals.

To Edison are to be credited two unusual motors. The

17 For the tasimeter, see Chapter VIII, p. 83.—"Odorscope" is the form preferred by the dictionaries; but even this is, like "cablegram," irregular.

first was based on something long known to experimenters, namely, the effect of temperature on magnetism. Common magnetic iron undergoes many changes as it is heated. At a dull red heat it becomes non-magnetic. Edison's pyro-magnetic motor accordingly consisted in its essentials of an electro-magnet and a pivoted iron bar that could be first heated, then cooled. When hot, the bar was not attracted to the magnet; when cold, it was attracted. Thus motion resulted. The Edison pyro-magnetic generator utilized the same principle—the energy of heat being converted into electrical energy.

The other motor was the phonomotor (or voice-engine), a curious "philosophical toy." A person talked against a diaphragm; the diaphragm moved a pawl; the pawl turned a ratchet-wheel that revolved a pulley. From the pulley a cord ran to a cardboard figure that would execute a mechanical movement, such as wood-sawing. The phonomotor had its place in Edison's study of diaphragms, by which he was aided in reasoning out the phonograph. It opens up rather startling possibilities as to the power that might be derived from miscellaneous speech now cast so wastefully upon the air.

Such are some of the further accomplishments that could more conveniently be grouped here than introduced into the main narrative of Edison's story. Though but a few out of many, they indicate the man's versatility, the reach of his interest, the sweep of his ideas. Inventions, projects, notions, hints were his common fare, and even the crumbs had elements of worth. It would seem that he could conduct widely differing researches at the same time, or turn from one field to another and back again, without confusion or sacrifice. Sometimes a subject took a place in a larger course of study and experiment; some-

times it was dropped because Edison did not think it could be profitably utilized just then or because he had hit upon something he considered better. Sometimes it was crowded out. Again, it might be forfeited because of the failure of Edison's business or professional associates to grasp an opportunity—as in the case of his electric-railway work. Or it might be turned over to the public, for others, if they would, to develop and improve. But whatever might happen, always there was something else to do, and every hour was "a bringer of new things."

One scarcely knows where he may next encounter a trace of Edison, a touch of his influence. The derived use of the word "filament" as an electrical term, is attributed to him. He introduced paraffin paper, now so commonly used for sanitary wrappings.

Perhaps the most serviceable miner's electric safety-lamp is the one invented by Edison. The current for it is obtained from a special type of Edison cell strapped to the miner's belt.

It is stated that "Hello!" as a preliminary call-word in telephone talk, was first heard in the Menlo Park laboratory when Edison was developing a transmitter for Bell's invention, and from Menlo was carried over the world. Bell's original call-word was "Ahoy!" In 1876, in testing his line between Boston and Cambridge, Bell called out "Ahoy! Ahoy!" to Thomas Watson, his apparatus-maker, who was stationed at the other end. "Ahoy!" Watson sent back. "There is nothing the matter with the instruments."

Of "Hello!" the "Century Dictionary" tells us: "As a greeting its use is confined to easy colloquial or vulgar speech." "It is to be regretted," the "New York Evening Post" once said,[18] "that Dr. Bell did not perpetuate

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the practice of 'ahoying' along with his invention itself, and that for such a lusty shout, such a round, ringing call, should have been substituted the present 'Hello,' a vapid, flat, meaningless term in comparison. How efficacious 'Ahoy!' would have been in smoothing over difficult telephone interludes, and in making the crustiest interlocutor affable with its jovial sound; in waking the sleepiest office boy to alertness with its heartiness; in pleasantly agitating the imagination with its nautical associations." Nevertheless, "Hello!" for telephone use spread at once, not only in the United States but elsewhere; though Englishmen clung to the more dignified and euphonious "Are you there?"

After his period of active service as president of the Naval Consulting Board,[19] Edison devoted himself to that never-completed task of improving his existing inventions, to executive duties, to chemical experimenting. Chemical experimenting, by the way, was always a favored diversion with him. Even at his Florida residence (about a mile from Fort Myers, on the Caloosahatchee river and near the west coast), where he was accustomed to pass a few weeks of winter, he had a chemical laboratory and a small machine-shop. In August, 1924, when, with Henry Ford and Harvey Firestone, he stopped at Plymouth, Vermont, to call upon President Coolidge, who was taking a brief vacation there, Edison was asked by reporters, "What about your inventions?" He quizzically answered, "I have several irons in the fire. Now and then I pull out a little one."

If to Edison's bona-fide inventions were added the fictitious devices ascribed to him, especially during the years at Menlo Park, the list would be yet more formidable.

[19] See Chapter XIV.

One would include the yarn, related with solemn plausibility and bearing indisputable ear-marks of "Sunday-newspaper science," about the Edisonian plan for melting snow as it fell. Huge mirrors, it was gravely explained, were to reflect rays obtained from the sun or from powerful electric lamps. This method was to solve forever the problem of snow removal in cities, but to be particularly valuable in keeping railway tracks constantly clear.

Wilder still, but none the less believed, was the diverting announcement of the Stratified Shirt. This was concocted by a reporter who, sent to get an "Edison story" and failing to run down an authentic one, more than made good the lack. Edison, so went the account, considered his patent shirt his greatest achievement. It had a bosom or front composed of three hundred and sixty-five layers of a thin fabric whose exact nature was a "trade secret." Each morning, on dressing for the day, all that an owner of one of these remarkable garments needed to do was to remove the top layer and presto! he had a new shirt, without spot or blemish—at least so far as concerned the bosom. Reprinted from China to Peru, the item evoked a flood of letters from persons wishing to inquire about these shirts; to order them (check or draft being sometimes inclosed); to take an agency for them. They seemed truly to fill a long-felt want. Said Edison: ". . . If I could have got hold of the young man, . . . I guess he wouldn't have wanted a shirt or anything else on his back for a few weeks." [20]

It is to be added that Edison, during early incandescent-lighting days, prepared a manual of instruction on the isolated electric plant; and that he contributed a few articles to general magazines and the technical press.

[20] Jones, p. 190.

Vague allusions have been made to a "treatise on electricity" that he wrote when he was for the second time in Louisville as a telegraph operator. At one time he undertook to collaborate with George Parsons Lathrop on a fiction "thriller" in which it would appear that amazing inventions, previously unheard of, were in some way to be introduced—possibly after the manner of Jules Verne or of H. G. Wells, with a wealth of convincing scientific detail. After a while he withdrew from this literary partnership; and the book, if it now exists at all, exists as an unpublished fragment.

XVI

WHAT MANNER OF MAN?

So far as now is known, the camera's first likeness of a human being was the daguerreotype portrait Dr. John W. Draper of New York University made of his sister Dorothy in 1840. In 1847 Edison was born. He grew up with the art of photography; and that art, to which he personally contributed the motion-picture camera, gave us more records of him than of any other American private citizen of his time. Examining these photographs, one is struck by the fact that, in spite of the years, Edison's face kept unmarred and unblurred to a remarkable degree the indomitable cast of youth. Similar evidence, to a less extent but with an even greater authority, is given in the works of painter and sculptor.

Five feet, nine and one-half inches in height, Edison as a telegraph operator was decidedly thin. As a young inventor, in the Newark and earlier Menlo days, he was spare. Nearing forty, he became somewhat fuller of figure; at the same time his face grew less oval of outline. It was a distinctive face—large, calm, candid, friendly, strong. From it looked uncommonly liquid and brilliant gray eyes. The chin was firm; the mouth large, finely-moulded, and sensitive; the nose prominent. Above the generous but closely-set ears the head rose dome-like. Dark hair, already grizzled, was parted at the right, and usually a lock or two of it hung loosely over the left side of the high forehead. It was a face in which what is

conventionally called the dreamer was blended with the man of action.

In an article in "Scribner's Monthly" (the present "Century") for November, 1878,[1] William H. Bishop, journalist and author, told of an evening spent in the Menlo laboratory, where he discovered Edison "bending intently above some detail of work." "The hands are stained with acid, and the clothing is of an ordinary 'ready-made' order. . . . He has the air of a mechanic, or more definitely, with his peculiar pallor,[2] of a night-printer. His features are large; the brow well shaped, without unusual developments; the eyes light gray; the nose irregular, and the mouth displaying teeth which are, also, not altogether regular. When he looks up his attention comes back slowly, as if it had been a long way off. But it comes back fully and cordially, and the expression of the face, now that it can be seen, is frank and prepossessing. A cheerful smile chases away the grave and somewhat weary look that belongs to it in its moments of rest. He seems no longer old. He has almost the air of a big, careless school-boy released from his tasks."

Broad-shouldered, deep-chested, Edison was built for endurance and labor. His weight at about his fortieth year reached one hundred and seventy-five; and for twenty-five years it remained so constant that all his new suits, it is said, were made by a New York tailor that never saw him, an old suit having been taken as guide to the measurements. This weight is, to be sure, some ten pounds above the average that insurance and other tables have generally fixed for men of his height. Edison

[1] Pp. 95–96.

[2] This pallor has been referred to by others. In 1923 a newspaper article ("The World," February 9) said: "He is pale, as always, but there is a healthy tint in the pallor." Dyer and Martin, however, mention his "good color" (II, 773).

is, however, no average man; and though his girth may have slightly increased after he was sixty-five, he has never given the impression of superfluous bulk. Even to-day he could not well be called portly.

In 1911 William Inglis thus vividly sketched him: ". . . The hair, white now, lies sprawled about in wisps that reveal the scalp here and there. In curious contrast are the inky-black, thick eyebrows that jut out from the base of his big forehead. The eyes are—by electric light, at least—a deep, gray-greenish blue, like very dark, unpolished jade. They do not gleam or glisten; yet, when he speaks, they have a curious glow that seems to penetrate one's inmost mind. The longish nose and deep chin were familiar from thousands of portraits; but there was one characteristic I had never seen in any portrait—the broad, often-smiling mouth. . . . There is something careless, winning, and yet dynamic about that smile." . . .[3]

"Edison's hands are," he adds, "worth a great deal of watching. They are not muscular hands at all, but long and hollow-backed, the hands of the dreamer, the idealist, the man of imagination. The fingers are ten slim antennæ, full of speculation; the backs of the hands, from wrist to knuckles, are actually a little concave. . . . Looking at the hands alone, one would classify Edison as one who lives entirely in the world of delicate but vast imaginations. It is the squareness of the jaws [*sic*], the width and depth of the back head and the fulness of the torso that indicate his limitless combativeness and robust energy in following his glorious imaginings to the uttermost end, regardless of obstacles."

Four years later, when he had become president of the Naval Consulting Board of the United States, he was

[3] "Harper's Weekly" for November 4, 1911; p. 8.

thus referred to in the Washington correspondence of the "Nation":[4] "A casual glance at the man would give you but a slight suggestion of a genius. . . . When you meet him, however, and he takes your hand and looks into your eyes, you begin to compass him mentally. The large, somewhat heavy face acquires a cheerful life you had not seen in its set lines before, and the stocky frame beneath seems to relax as he talks to you. Conversation, by the way, has been more a duty than a pleasure to him of late years, as his deafness has been steadily on the increase."

At first considered a somewhat delicate child, Edison soon outgrew that phase, and the ingratiating daguerreotype of him in his train-boy days shows him sturdy and good-humored. Illness he has hardly known. He inherited a hardiness that withstood constant sustained work, a nervous system of rare balance. T. C. Martin is authority for the story that "in the early days" one of Edison's laboratory staff—a "very famous inventor"—went to Edison one morning and "begged to be told the real secret of such uncanny powers of endurance, so imperatively necessary in a place which knew neither night nor day." With no thought that the remark might be taken seriously, Edison carelessly replied that he ate a Welsh rabbit for breakfast every morning. Each morning for six weeks the "ingenious interlocutor" followed the prescription—"then, well-nigh perishing, placed himself in the hands of an incredulous doctor!"

If Welsh rabbit was not the secret—and manifestly it was not—what was? Not some hobby, for Edison had no hobby save more work. Not recreation, for about all the recreation he had in those days was an infrequent fishing excursion along the New Jersey coast. Later, he now

[4] October 28, 1915: "Notes from the Capital."

and then played a game of billiards, and his Llewellyn Park house contained a billiard-room; but the only indoor sport he ever showed much interest in was the ancient East Indian game of *pachisi*—known to Occidentals as parcheesi. Outdoor games he did not play. A vacation was a rare event. What, then, was the answer?

Fundamentally we are not, of course, likely to learn what it was. Such men do not easily surrender their secrets—are not glibly explained. Browning says,

> "Outside should suffice for evidence." . . .

At all events, we can only note things more or less on the surface. There was a constitution of marked stamina and resistance. There was much common-sense in the matters of diet and dress.[5] There was such nervous stability that sleep, even when brief, was instant, unbroken, and wholly restful. There was relief through change of work. There was a temperament expressed in the words, "Spilt milk doesn't interest me." Also, there was a certain well-considered *pace* in his way of living and working.

The present writer was once shown through a brass-rolling mill, and he commented on the deliberate manner of a particular group of workmen. He was informed that these men were constantly employed in handling heavy masses of metal, and that the deliberateness was the result of experience. At this leisurely *tempo* the work was best accomplished and the strength of the workers best conserved. It was thus that Edison went about his tasks. Nobody, it seems, ever saw Edison lazy; nobody, by the same token, ever saw him in a hurry.[6] He worked with a concentrated steadiness and an interminable pa-

[5] "Much liquor," he is quoted as saying, "is a bad thing for any one who wants to go through life and work in earnest." (Jones, p. 295.)

[6] D. and M., I, 263.

tience. In other words, his style was not that of the "Standardized American Citizen"—"the fellow with Zip and Bang"—booster of "the tenets of one-hundred-per-cent pep"—so glowingly celebrated in George F. Babbitt's immortal speech at the dinner of the Zenith Real Estate Board.

When the motor-vehicle came in, Edison found time for occasional tours. With advancing years, a fortnight's motor-car jaunt in the company of friends became an annual event. Then, too, the winter sojourn in Florida was lengthened, and there Edison and his pal Henry Ford would take fishing trips up the Orange river. Occasional holidays were had. Daily working hours were cut down (by 1923 they were only about sixteen!) and so was the daily ration of black cigars and black coffee. Food was more carefully and more frugally selected, the menus including little meat but plenty of fruit. At the regular birthday luncheon tendered by the Edison Pioneers, the "Old Man" would have dishes specially cooked for him or would bring his meal from home in a tin box. For those that care to know, it may be recorded that at the 1924 luncheon he had grapefruit cocktail, sardines, spinach, stewed tomatoes, and a glass of milk. "Then," said the press account, "he lighted a cigar and mouthed it thoughtfully, talking with no one. . . . Only at rare intervals did he so much as smile." [7]

In 1921, at his regular birthday interview, he told the reporters assembled that he wasn't at all bothered by any question as to how a man over seventy might pass his days. "If," he assured them, "a man encounters that difficulty, the trouble is that he didn't take interest in a great number of things when he was mentally active in his early years. If he was mentally active enough he would find

[7] "The World," February 12, 1924.

plenty to occupy his time in reading, observing and watching people." . . . A man that "retired" at seventy might, he thought, expect to die within three years. He added: "I don't want to retire. When the doctor brings in the oxygen cylinder I'll know it's time for me to give up." [8]

On his seventy-fifth birthday he responded to the stated query about how he felt: "How do I feel? Like a two-shift man always feels—well." He thought that on his seventy-sixth birthday he was just in his prime. On his seventy-seventh, asked: "What is your philosophy of life?" he answered in writing:

"Work. Bringing out the secrets of nature and applying them for the happiness of man. Looking on the bright side of everything." [9]

On May 13th, 1924—three months after his seventy-seventh birthday—he unveiled a bust of Joseph Henry in the Hall of Fame, New York University. "On that occasion," wrote William H. Bishop (himself about the same age), "he sat with his hat off for hours on the platform, in a wintry breeze that would have almost killed anybody else." [10] That evening he attended a motion-picture showing in New York; and when his motor-car started for Llewellyn Park, he was riding with the chauffeur on the open front seat—overcoatless, though light overcoats were being worn by the majority of men afoot.

He uses glasses for reading and close work but not for general purposes—this in spite of the fact that for sixty years his eyes have been unsparingly active, much of the time by artificial light. W. S. Mallory, one of Edison's associates, has stated that he was once present when Edison's eyes were examined by an oculist unaware who the

[8] "New York Tribune," February 12, 1921.

[9] "The World," editorial, February 13, 1922; "New York Tribune," February 11, 1924; *ib.*, February 12.

[10] In a personal letter to the author, February 18, 1925.

inventor was. Said the oculist to Mallory: "I . . . have never seen an optic nerve like that of this gentleman. An ordinary optic nerve is about the thickness of a thread, but his is like a cord. He must be a remarkable man in some walk of life." . . .[11]

Edison the telegrapher is described as uncouth in manner and rough in dress.[12] His carelessness as to dress and general appearance has in later days been somewhat exaggerated. His tastes in apparel have, it is true, been always of the simplest. He prefers subdued colors, quiet patterns. Furthermore he believes that all clothing should be worn loose. His waistbands are liberal. So are his shoes—"as big as his feet and then some." Uniformly his choice of collars has been one of the "rolling" variety, exceedingly low, or one of the sort that gapes broadly in front, permitting a free Adam's-apple—a sort akin to that which another Grand Old Man, Gladstone, made famous in Victorian times. With the collar went either a bow-tie or a string-tie, white or black.

The tradition of Edison's extreme carelessness in clothes dates, probably, from the Menlo Park period, especially those years of it when he was introducing and developing his incandescent-lighting system. Visitors to the laboratory were likely to find him in nondescript clothing discolored with chemicals and decidedly well worn —such clothing as in the circumstances, under the existing conditions of work, was suitable enough. A group taken in 1878 by Isaacs, the staff photographer, on the piazza at the front (eastern) end of the laboratory building, shows Edison no more rough-and-ready than most of his associates. But rough-and-ready he undoubtedly was, judged by the ultra-conventional standards of the aver-

[11] D. and M., II, 763.

[12] *Ib.*, I, 68, 103.

age business or professional man of that starched and frock-coated period. When mains were being laid for the Pearl-street station in New York, Edison, laboring four evenings a week in street and trench, sleeping casually in a cellar upon a pile of tubes, was beyond question not arrayed like a member of the board of directors of the Edison Electric Illuminating company. Then, too, carelessness in attire was taken to be one of the stock attributes of genius, and newspapers played it up as a helpful ingredient of Edison's picturesqueness. They did much the same kind of thing in the case of the late Charles P. Steinmetz.

It cannot, indeed, be said of Edison, as Carlyle said of the Dandy, that every faculty "is heroically consecrated to this one object, the wearing of Clothes wisely and well." . . . The whole subject of clothes "rather bores him." He does not "scorn the shocking hat." For a while a disreputable duster—a kind of "masculine 'Mother Hubbard' "—and a battered straw "cady" formed part of his laboratory costume. He has been heard to chaff at spats and swallow-tailed coats. "At seventy-five," he once threatened, "I expect to wear loud waistcoats with fancy buttons"— but he did not execute the threat. He doesn't sport a top-hat and he isn't fond of carrying gloves. Yet visitors at the West Orange works have marked the neatness of his linen, have even fancied they discerned a certain Quakerish finicalness of garb. He has been photographed in a dinner-jacket (looking quite modish and thoroughly at ease, too!) ; and when he unveiled the bust of Joseph Henry in the Hall of Fame, he appeared in an afternoon coat of unexceptionable cut and trousers smartly creased. They do say that the second Mrs. Edison has been a modifying influence—but be that as it may.

Edison was constitutionally able to get along with relatively little sleep. This capacity enabled him to serve as a night telegraph operator and then study and do extra work during a good share of the day. In Boston he devoted from eighteen to twenty hours to his job, his reading, and his special experimenting. In Newark "half an hour of sleep three or four times in the twenty-four hours was all he needed."[13] At Menlo he knew no such thing as a regular quitting-time. At West Orange in 1888, while developing the wax-cylinder type of phonograph, he put in five days and nights of continuous work; and this remained his record performance.

In 1920 T. C. Martin wrote:[14]

"Edison sleeps well at seventy-three. When he sleeps he does nothing else. He never dreams, nor is he restless. He seems to have the faculty of getting more rest out of two hours than most men get out of six or eight. A short time ago he was working all around the twenty-four-hour clock, went to bed at half-past five one morning and was up at seven, having had about one and a half hours of real sleep. When he went to breakfast he was asked, 'How do you feel this morning?' and he replied, 'I would feel better if I had not overslept myself half an hour.' "

A cot was placed for him in an alcove of the library in the West Orange laboratory, and there, after long exertion, he would slumber peacefully, his right cheek resting on his hand. Waking him was no easy matter.

It is hardly to be wondered at that such a man believes folk as a rule sleep too much. When, touring with Ford and Firestone, he stopped in August, 1924, at Plymouth,

[13] D. and M., I, 134.

[14] In his pamphlet "Edison at Seventy-three."

Vermont, to call upon President Coolidge, he asked Mrs. Coolidge, "How much does the President sleep?"

"Too much, I think," said she. "He takes a nap after dinner and sleeps until four, and then goes to bed early at night."

To which Edison with finality responded, "Lack of sleep never hurt anybody." [15]

He used to have a story of a man who applied to him for a position. This man was, by his own statement, a martyr to insomnia, so Edison thought him a first-rate find. "I put him to work on a mercury pump, and kept him at it night and day. At the end of sixty hours I left him for half an hour, and when I returned, there he was, the pump all broken to pieces and the man fast asleep on the ruins." . . .[16]

Edison gives an impression of simplicity, freedom from "side," an essential humility. Years ago, in applying for membership in the Engineers' Club of Philadelphia, he thus stated his professional achievements: "I have designed a concentrating plant and built a machine-shop, etc., etc." When the "Independent," in 1913, took a referendum of its readers as to the ten Americans whom they considered most useful and most nearly indispensable, Edison led, his name appearing on eighty-seven per cent. of the lists. Declining the editor's request for an article, he replied in part thus:

"Modesty forbids any comments on my part concerning the result of the poll of your readers. The only thing that troubles me is the fear (in which my wife shares) that if these things keep up I may get a swelled head. When I look over the list of names of those for

[15] "Herald Tribune," August 20, 1924.

[16] Jones, p. 224.

whom your readers have voted, I am at a loss to express my feelings concerning the honor they have done me." [17]

He has told about going to Philadelphia to attend a dinner given by George W. Childs for Joseph Chamberlain. The trip was made in the private car of Roberts, then president of the Pennsylvania railroad. When Edison returned to the Philadelphia station, Roberts was on hand and insisted upon carrying Edison's valise for him. "I never," protested Edison, "could understand that." [18]

When Waldo Warren asked him whether he had "maxims or conclusions"—"things you have found out, fundamental laws"—that he could give to other inventors, Edison rejoined:

"Ah, these men know more about their own work than I could tell them. I haven't any conclusions to give; I am just learning about things myself." . . .[19]

During the same interview he mused:

"I have tried so many things I thought were true, and found I was mistaken, that I have quit being too sure about anything. All I can do is to try out what seems to be the right thing, and be ready to give it up as soon as I am convinced that there is nothing in it." [20]

His unpretentiousness has at times had its rather provincial and amusing side. In 1889, during the Universal Exposition, he visited France and was made a commander of the Legion of Honor, of which he was already a chevalier. "My wife," he has said, "had me wear the little red button, but when I saw Americans coming I would slip it out of my lapel, as I thought they would jolly me

[17] "The Independent," September 4, 1913.

[18] D. and M., II, 745.

[19] W. P. Warren, "Edison on Invention and Inventors," in the "Century Magazine" for July, 1911; p. 419.

[20] *Ib.,* 417–418.

for wearing it."[21] Possibly Edison himself is jollying!

If he is, in the words of one observer, "a simple, democratic old man,"[22] it is likely that his sense of humor is in part responsible. He has enjoyed telling jokes at his own expense: how, for example, having rented the machinery in one of his Newark shops when he removed to Menlo Park, he heard no more of it and three years later visited Newark to find a hotel where the shop had been; how at Goerck street he tried to terrify Sitting Bull and other Sioux with a violent electric arc—and failed utterly; how at Menlo, when the potato-bug was a novel pest, he sprinkled bisulphide of carbon on the potato-vines of a farmer who had sought his aid, with the result that he destroyed not only bugs but vines as well and had to pay $300 damages.

To mark the forty-fifth anniversary of the phonograph's first appearance in a working model, phonograph distributors presented to him a crayon portrait of himself. After close inspection of it, his only comment was: "I look like a United States Senator there." Which may or may not reveal his opinion of the portrait as a work of art. Near his desk in the West Orange laboratory hangs—or did hang—a cartoon showing him toiling away while two scientists, vainly endeavoring to see him, are intercepted by a negro porter. The porter impressively warns: "Sh! De Wizard am embossed in thought, gemmen, and he cain't be introrupted. He hain't et er slep' fo' fo' days."

An English writer found it remarkable that Edison should be able "at any moment to lift himself out of his scientific surroundings and enter glibly into the lightest

[21] D. and M., II, 748.

[22] G. E. Walsh, "With Edison in His Laboratory," in "The Independent" for September 4, 1913.

of light conversation, with all the *abandon* of irresponsible youth." True it is that he has always had the American fondness for swapping stories; that having seen the funny side of things as he went along, he has been filled with amusing reminiscences. He seems to have regarded humorless men—even a friend like Henry Villard—in a kind of puzzlement. The "lean and hungry look" of the unsmiling Jay Gould repelled him. He has chuckled over the remembered spectacle of Werner von Siemens endeavoring to interpret American jokes to Hermann von Helmholtz. Or of Bergmann—"little Bergmann," who made electroliers, meters, and such things for the Edison lighting system—issuing orders that the factory whistle was not to be blown after Edison had shown him three or four foolscap sheets of figures and solemnly assured him they were calculations proving great loss of power through the blowing of the whistle.

Probably the best known of Edison's *bons mots* is his analysis of genius: "Genius is 1 per cent. inspiration and 99 per cent. perspiration." This is a kind of restatement of Carlyle's "transcendent capacity of taking trouble, first of all." [23] Needless to say, this analysis, though flattering to mediocrity, is, like all other epigrams about genius, unsatisfactory. One likes better his reply when asked why a certain man no longer was in his employ: "Oh, he was so slow that it would take him half an hour to get out of the field of a microscope." Or his counsel to the member of the building committee of a Philadelphia church who consulted him about the advisability of placing lightning-rods on the new edifice: "By all means.

[23] "Frederick the Great," IV, iii. The "first of all" is invariably omitted and the remainder almost invariably misquoted. See the "Encyclopædia Britannica," 11th ed., art. "Genius."

You know, Providence is sometimes absent-minded."[24] Or his suggestion as to how electricity might best be applied for executions: "Hire the criminals out to some of the New York electric light [*i. e.*, arc-lighting] companies." When, on Broadway, he avoided a meeting with his chief legal adviser, a friend sought the reason. "Why," explained Edison, "I was afraid to shake hands with him again until I found out whether I could afford to pay his fee for it."

Not always is he good-natured. "Those in closest touch with Edison," wrote the late T. C. Martin, "are constantly impressed with his moderation and patience in personal relationships; and, truly, he has reaped his reward in general good-will. Yet even now [in 1920] he occasionally uses language somewhat removed from benediction; and what a glorious hater he can be on occasion!"[25]

". . . Often"—so says Bailey Millard[26]—"he is in the highest spirits, whistling and joking—then depressed, sullen, and angry. His patience applies only to his labor. With the men about him, particularly those who are not very keen, he has no patience whatever. When he is in bad humor, word passes quickly about among the five thousand employés in his big shops that 'the old man is on the rampage today,' and everybody who can possibly do so keeps away from him. Once, when he was in such a humor, I saw him turn upon an employé who had

[24] Was this a belated echo of the curious protest that arose when another Philadelphian, Benjamin Franklin, devised the lightning-rod? Franklin was accused of interfering with divine action, and churches were especially slow in adopting the supposedly impious protection!

[25] "Edison at Seventy-three."

[26] "Our Twelve Great Scientists. VI. Thomas Alva Edison," in the "Technical World Magazine" for October, 1911.

forgotten to wind up a phonograph, and vent upon him such wrath as made the delinquent wince visibly. His arguments are fulminations. He pounds the table and shouts angrily. As he is extremely deaf, his opponent—as he insists upon regarding anyone who does not agree with him—must raise his voice to a high pitch, so that what Edison apparently considers a mild debate often resembles the hottest kind of row." A man that visited the West Orange laboratory in answer to an advertisement for a production engineer, described Edison as pacing back and forth, "irritably demanding why certain results were not being obtained in his factory and denouncing what he termed bone-headed moves on the part of his executives, while the latter shouted their excuses into his deaf ears." [27]

It was quite in the nature of things that Edison's peculiarly individual way of working and his insistence upon it, his more or less blunt disregard of aught save the goal he had in view, would not be wholly congenial to all his more immediate co-workers, especially on the research staff. His essential fairness and justice have, however, always been insisted on by those who may be supposed to know him best. W. S. Mallory once went so far as to say, "I doubt if there is another man living for whom his men would do as much." That he can show forbearance is indicated by an anecdote related in connection with the theft of seventy-eight of his electric-lighting inventions. A dishonest patent-solicitor did not file the applications he was supposed to file, but sold them to other persons. These persons then signed new applications and thus fraudulently took out patents on Edison's work. Edison confessed that this incident "has left a sore spot in me that has never healed." Yet he would not mention

[27] "The New York Times," May 11, 1921.

that patent-solicitor's name, merely observing, "It is of no practical use. . . . I believe he is dead, but he may have left a family." [28]

At Menlo Park, on the upper floor of the office-building, Edison had a reference-library for the use of himself and the staff, and at West Orange was assembled one much more comprehensive—a fine collection—as part of the equipment of his laboratory. In connection with his work he has leaned heavily upon "book learning." The assumption sometimes encountered that Edison is a sort of improvisator, purely original and underived, scorning classified knowledge, impatient of all precedent, is but one of many errors regarding him. He is himself authority for the statement that, aside from special research, for which he has collected and studied vast quantities of printed matter, he has also constantly read in such favorite subjects as astronomy, biology, mechanics, metaphysics, music, physics (including, of course, electricity), and political economy. In addition to this, he has kept fully in touch, through scientific journals and proceedings of scientific bodies, with new developments in science.

The closeness with which he can read when exploring a subject may be judged by an experience of one of his assistants. In this case the subject happened to be a portion of the mechanism of typewriting-machines. Edison ordered that arrangements be made with the manufacturers of every available form of machine to have a specimen at the Edison works on a certain date and with each machine a representative to explain it; also that all the books treating of this particular mechanism be assembled from the library. The evening before the day appointed, these books were sent up to the house. The

[28] D. and M., I, 341–343.

experts, when they appeared, were amazed to find Edison so familiar with the subject that he was able to correct certain of their statements. Curious to see how long it would take him, the assistant set out to read the references that Edison had evidently absorbed at a sitting. They required all his spare time for eleven days.[29]

Ever since he was a train-boy, when, between trains, he essayed to read his way, alcove by alcove, through the Detroit public library of the time—ever since he was a telegraph operator, when he browsed in the second-hand book-shops and was sometimes called "Victor Hugo" Edison because of his fondness for the Frenchman's works, he has done, too, some reading in miscellaneous *belles-lettres.* Reported among his later preferences in fiction are the romances of Dumas and Jules Verne and the "thrillers" of Gaboriau. As for poetry, he has said: ". . . I can't stand jingle. Where the thought is twisted out of shape just to make it rime—I can't stand that. But I like 'Evangeline,' 'Enoch Arden,' and things like that. These I call true poetry.

"But, ah, Shakspere! That's where you get the ideas! My, but that man did have ideas! He would have been an inventor, a wonderful inventor, if he had turned his mind to it. He seemed to see the inside of everything." . . .[30]

Of his literary predilections, little else is known. What, if anything, he thinks about contemporary literature, has not been divulged. It is said that he somewhat depends on the judgment of Mrs. Edison and is inclined to accept her recommendations.

29 French Strother, "The Modern Profession of Inventing," in "The World's Work" for June, 1905.

30 W. P. Warren, "Edison on Invention and Inventors," in the "Century Magazine" for July, 1911; p. 418.

Misconceptions have been common as to how Edison arrived at his results. These misconceptions may be classified as largely of two varieties: those that held he was guided by sudden bursts of supreme insight, and those that held he tried everything, hit or miss, until by main strength he succeeded. Now, as a matter of fact, Edison's method in developing an idea may be called a method by elimination. He starts out in absolute indifference to whatever difficulties may theoretically exist. He thoroughly studies what previously has been learned and done that may in any way bear on the subject—searching everything available in print. Then his assistants try things; and in laboratory note-books is kept a detailed record of the processes. For example, he wished at one time a chemical mixture having "two properties that are rarely found together in the same compound." He might, proceeding from the known to the unknown, have had his chemists first determine what chemicals were most likely to fill the bill and then try those few. What he actually did was to turn to Watts' "Dictionary of Chemistry" and from the formulæ there given have every sort of mixture prepared that could be imagined even remotely to be of use. Edison's summary was: "Out of the lot, I found about seven compounds that worked, but when I finished the experiment I knew beyond a doubt that those seven were the only ones that could be made for that purpose." [31]

The late Dr. R. C. Maclaurin warned us, however, that it is a mistake to set up Edison "as a 'practical man' in the narrow sense." "It is true," said Doctor Maclaurin, "that he has described himself as 'pure practice' in distinction from Mr. Steinmetz, whom he has called 'pure

[31] French Strother, "The Modern Profession of Inventing," in "The World's Work" for June, 1905.

theory,' but this, of course, was a joke. Newspaper men have expanded it so as to make it appear that Edison knows nothing about science, cares nothing for the achievements of the great experimenters and thinkers who have preceded him, and merely tries everything he can think of until he happens upon what he is seeking. Few things more absurd could be suggested. He is no slave to theory; he is ready, as every scientific man is ready, to try anything that seems reasonable, but practically always he has what seems to him a good reason for everything that he tries. In the rare cases where he has tried blindly, it has been because there was absolutely no light."[32]

"Not only," declared Doctor Maclaurin, "has he shown his faith in science by great achievements, but he has proved himself a great force in education by giving so brilliant an exhibition of the *method* of science, the method of experimentation." And he finds it interesting to reflect what Edison's acquaintance with Faraday's works, purchased second-hand in Boston while Edison was still a telegraph operator, has meant for the world. One thinks of the 1,600 tests of earths, minerals, and ores in making metallic-wire filaments for the Edison incandescent lamp; of the 6,000 distinct species of plants (chiefly bamboos) that Edison tried as material to be carbonized into filaments; of the 50,000 separate experiments made in developing the nickel-iron storage battery; of the patient improvement of the telephone, the phonograph and its ancillary devices, or the motion-picture camera. The laboratory note-book record is said to show that one of his assistants alone once conducted a series of about 15,000 experiments in connection with a problem

[32] In an address before the Civic Forum, New York, on May 6, 1915, when a medal for public service was presented to Edison. See p. 178.

to which Edison was then devoting particular attention.

In brief, Edison's way has been the way of knowledge, close research, and persevering hard work. But in addition to all this, men who have long been associated with him are wont to refer to his direct apprehension—his "guesswork," as he styles it. Said F. R. Upton: "One of the main impressions left upon me after knowing Mr. Edison for many years is the marvellous accuracy of his guesses."[33] ". . . Very many times," said W. S. Mallory, "I have heard Mr. Edison make predictions as to what a certain mechanical device ought to do in the way of output and costs, when his statements did not seem to be even among the possibilities. Subsequently, after more or less experience, the predictions have been verified."[34] . . . One of Edison's engineers has added that Edison "seems to carry in his head determining factors of all kinds, and has the ability to apply them instantly in considering any mechanical problem."[35] At a time when little was really known about dynamos, he contrived, against such precedent as there then was, to build a dynamo with small internal resistance and thus delivered ninety per cent. of the energy produced. It is said that when asked how his earlier dynamos came to be so much superior to anything that had preceded them, he would answer, "Well, I happened to be a pretty good guesser."[36]

Again, his own words were:

"One question concerning this early system has often been asked, namely: 'Why did I fix 110 volts as a standard pressure for the carbon filament lamp?' The answer to this is that I based my judgment on the best I

[33] D. and M., I, 297.
[34] *Ib.*, II, 512.
[35] *Ib.*, II, 621.
[36] Jones, p. 324.

thought we could do in the matter of reducing the cost of copper and the difficulties we had in making filaments stable at high voltages. I thought that 110 volts would be sufficient to insure the commercial introduction of the system, and 110 volts is still the standard."[37]

This inherent grasp of things may be regarded as a mark of inventive imagination. "Imagination," Edison has affirmed, "supplies the ideas, and technical knowledge carries them out."[38]

His laboratory note-books are filled with sketches by him. Whether in the laboratory, discussing a new idea, or in the home, during an evening of talk, he has always had a way of seizing on pieces of paper and covering them with rude drawings to illustrate what he was saying. This was likely to be accompanied by tricks of tapping with the pencil or of tugging at his bushy eyebrows, which retained their dark color after his hair had turned white. As his deafness increased, his voice took on the somewhat flat, colorless tone so common among persons of defective hearing.

Speeches by him have been extremely rare. When an after-dinner speech has been expected of him, or a response to an address, he has almost invariably contrived to provide a substitute. No doubt a small club might be formed of those who have served in this fashion and regard their service as a distinction. He has declared that he can't understand how any man makes a speech or writes a book. His first radio talk was given from Atlantic City, New Jersey, on May 19th, 1926, during the convention there of the National Electric Light Association.

[37] Quoted in T. C. Martin, "Forty Years of Edison Service" (New York, 1922); p. 15.

[38] W. P. Warren, "Edison on Invention and Inventors," in the "Century Magazine" for July, 1911; p. 416.

It consisted of the following twenty-two words: "Why, I don't know what to say. This is the first time I ever spoke into one of these things. Good-night."

But to his laboratory or wherever else he might be waylaid, newspaper men and magazine men have flocked to get him to talk; and they have spread abroad not only his accounts of his inventions, his comments on scientific affairs, or his predictions as to industrial developments of the future, but also his opinions on a wide range of topics, his personal views about almost every conceivable thing of which he would admit any personal view whatever. He has always been "good copy."

Even before the invention of the phonograph, the "Wizard myth" was taking form. With the appearance of the phonograph, and thenceforward for many years, it received large accretions. The dear public was ready to expect the marvelous from Edison; and the young lions of the press sometimes helped to supply the marvels. Nor was it merely that they added fantastic embroidery to the facts. ". . . The worst of it is," Edison once complained, "that these fellows who come out here [West Orange] go back without ever having seen me or heard me speak a word and write out alleged interviews that make me seem foolish to people who don't know me."[39]

Mingled with these "fairy tales of science" were unauthentic and confused yarns about Edison's career and more strictly personal history. Fictions of both these classes found place in magazine articles and in books. It is an interesting example of how legend may collect even in modern days and during the lifetime of the hero. By way of apology it has sometimes been hinted that Edison rather encouraged this sort of thing. It is possible that he has not been wholly unaware of the sweet uses of ad-

39 "Electrical Review" for January 12, 1901; p. 63.

vertisement; it is not improbable that some of his quiet "joshing" has been reported more gravely than he intended; it is certain that he could not keep a corrective or advisory eye on all the immense amount of material relating to him that has appeared in print. The fact remains that misstatements of all sorts have been widely circulated and some of them have reached an extreme that moved him to sharp protest.

In later years his judgments have constantly been sought by reporters and special writers and featured by editors. On his seventy-seventh birthday, for example, the allied interviewers submitted a long list of questions for him to answer in writing. When coal and oil are gone, whence shall we get power? Whom would he choose for President? What about Fundamentalists and Modernists? Has the modern young woman been too severely criticised? Shall we ever communicate with Mars? Even that ancient battle-horse of amateur debating societies, Is the world growing better or worse? And so forth. Readily and in a firm hand he wrote his terse answers, then turned straight back to his work.

It is the accepted thing for many American newspapers and for American magazines of a certain type to air the opinions of men who chance to be conspicuous figures in the world of commerce, industry, or finance; for on all sides it is taken as axiomatic that whatever such folk have to say about anything at all must be profoundly knowing. Not for this reason is Edison quizzed, but because Americans are interested in his flavorsome personality; respect his uncommon and stimulating mind; read what he says; highly esteem his opinions in fields in which they believe him experienced and informed; and are prone to find entertainment, even while they discount them, in what they may consider his prejudices, foibles, or errors.

In 1915, when the Franklin medal of the Franklin Institute was awarded to Edison, Dr. Harry F. Keller, in surveying Edison's achievements, declared: "I may say without fear of contradiction that no other inventor's name, either in this or any other country, has become so universally popular as his." [40]

In the earlier days of the electrical art in this country, a dispute—long since settled and largely forgotten—arose between the exponents of the alternating current on the one side and of the direct current on the other. To the former group belonged George Westinghouse. In his biography of Westinghouse, Francis E. Leupp says: [41] "Interviewers pursued Westinghouse wherever he went, trying to lure him into some explosive utterance against Thomas A. Edison, the chief exponent of the continuous current, which might produce a personal collision between the two inventors, and thus set free a fund of spicy 'copy.'" It has been stated on behalf of Edison that his electric-lighting system, as at first introduced, was planned for thickly-settled areas, wherein distribution by low-pressure, direct current was, he believed, the only really safe method; and that for transmission he considered alternating current, under proper safeguards, perfectly suitable. He had no inclination toward becoming a controversialist in his special field of work, but he did have definite convictions; and in the case of a public service like that of supplying electric current, and especially in view of the fact that in those pioneer days so little was known about electric systems anyway, he

[40] At a stated meeting of the Institute, held on the evening of Wednesday, May 19, 1915. See the "Journal" of the Institute for July, 1915.

[41] "George Westinghouse: His Life and Achievements." See pp. 148-151.

thought that in its own interest the public should be kept informed.

Some of his offhand utterances about matters not within his particular province have had the effect of stimulating answer and rebuttal—nor is it unlikely that he was aware of the possibility of such result. When in 1923 he predicted that motion-pictures would eventually oust books from schools, a chorus of dissent arose. When in 1910 he discussed the survival of human personality, the late Dr. William H. Thomson, whose volume "Brain and Personality" he had recommended, took issue with him, saying that some of Edison's remarks were very superficial and that Edison's view was "unscientific." "If Mr. Edison's objections are based on scientific facts exclusively," said Doctor Thomson, "he shows a great ignorance of brain discoveries." Others arose to label the inventor's statements dogmatic and contradictory.[42]

If one traces such records as exist, one will discover, however, that the bugbear of consistency has never seriously bothered Edison. At one time he has berated the colleges, at another has granted "College forces a young man to learn at least something when he doesn't want to." [43] The student will have a hard job in entirely reconciling Edison's assertions in 1910 regarding the survival of human personality, with his views as reported in the press in 1923, at the time when he attended the funeral of his friend and camping companion President Harding.[44] But who shall say that we may not here trace the scientific spirit? Of the scientist it has been said, "A theory is merely a tool, and he drops one theory and picks

42 See "Current Literature" for November and December, 1910.

43 "New York Tribune" for February 12, 1924.

44 See the "New York Evening Post" for August 11, 1923; "The World" of the same date. *Cf.* the "Scientific American" for October 30, 1920; pp. 446 *et seq.*

up another without a thought of inconsistency, just as a carpenter drops his saw and picks up his chisel." [45]

With respect to Edison's religious position, it may be noted that men that well knew him have described him as of a "reverential attitude of mind"; and that he himself has said: "Science cannot reach any other conclusion than that there is a great intelligence manifested everywhere." [46] His theological position, if he has one, has not been made clear; but of the struggle between Fundamentalists and Modernists he has said that it marks "the transition from myth to facts." [47]

It may not, all things considered, be wholly surprising to find Edison speaking slightingly of the so-called dead languages as instruments of intellectual discipline, or somewhat disparaging the cultural side of American life.[48] It may not be surprising to find him inexorable toward the cigarette, though he has been a steadfast chewer of tobacco and at one time smoked twenty strong cigars a day. It is, however, a surprise to discover him pooh-poohing mathematics beyond simple arithmetic. Though himself lacking mathematical faculty, tastes, or training, he has of course been able to obtain the services of mathematicians when he needed them—including those of such men as F. R. Upton and Arthur E. Kennelly, the second of whom later became professor of electrical engineering in Harvard University and the Massachusetts Institute of Technology.

In 1921 and later, Edison aroused a good deal of attention and comment through his "questionnaires"—lists

[45] E. E. Slosson, "Easy Lessons in Einstein" (New York, 1920); p. 100.

[46] W. P. Warren, "Edison on Invention and Inventors," in the "Century Magazine" for July, 1911; p. 417.

[47] "The World" for February 12, 1924.

[48] See D. and M., II, 768.

of questions to be answered by applicants for work as inspectors in the Edison plant. It was proposed that the men that passed the test should, if they made satisfactory progress, be promoted to executive and administrative posts. In the old days at Menlo Park, Edison had a different form of examination, judging from the story of J. H. Vail, who wished at that time to have charge of the dynamo-room. According to Vail, Edison pointed out a pile of junk and said, "Put that together and let me know when it's running." The junk turned out to be a dynamo; and after Vail had put it together and got it going, he was considered to have passed.[49]

For society in any formal sense, Edison has cared but little—for "society" in its pettiest sense, nothing whatever. In her volume called "The Social Ladder" (the general drift of which appears to be that there is no such thing as real "society" in America), Mrs. J. K. Van Rensselaer concludes that "Artists, scientists, educators, inventors, are far too busy in their own spheres to take on additional burdens for the sake of numbering themselves among the socially elect."[50] Certainly this is true of Edison.

He is fond of his home, over which the second Mrs. Edison has so well presided. Mrs. Edison is a cultured, gracious, accomplished woman, a director of the Playground and Recreation Association of America, and interested in other public movements. It was she who was selected to unveil the fine statue of Joan of Arc by Anna Vaughn Hyatt (Mrs. Archer M. Huntington) on Riverside Drive, New York. The other members of the family are Madeline (now Mrs. John E. Sloan), Charles (who is being trained to succeed to the general direction of the

[49] D. and M., II, 613–614.

[50] P. 135.

Edison companies), and Theodore. The first Mrs. Edison left three children—Thomas Alva, jr., William Leslie, and Marion, who married an officer in the German army.

In addition to the decorations and medals that Edison has received, he has also had conferred upon him three academic degrees: Hon. Ph.D. by Union College (1878); D.Sc. by Princeton University (1915); and LL.D. by the University of the State of New York (1916). It is perhaps worthy of note that the last-named degree was actually conferred by the telephone, toward whose perfecting Edison years ago contributed so much. President J. H. Finley, speaking from Albany to West Orange, addressed the candidate as "not *in absentia* but merely *in loco remoto*." [51]

Edison has been criticised for not being something he never professed to be—a "pure scientist," or, as the old-fashioned style had it, "natural philosopher." He has repeatedly made it as clear as he possibly could that with him the commercial availability of an invention has been the first point to consider. On this theme he enlarged as follows:

"The point in which I am different from most inventors is that I have, besides the usual inventor's make-up, a bump of practicality as a sort of appendix, the sense of the business, money value of an invention. Oh, no, I didn't have it naturally. It was pounded into me by some pretty hard knocks." [52]

". . . I always keep within a few feet of the earth's surface all the time," he told an interviewer. "At least

[51] See "Academic Honors for a Wizard," in "The Outlook" for November 1, 1916; pp. 481–482.

[52] French Strother, "The Modern Profession of Inventing," in "The World's Work" for June, 1905.

I never let my thought run up higher than the Himalayas." . . .[53] He defined a "successful invention" as "something that is so practical that a Polish Jew will buy it." Surely all this is explicit enough.

When Edison took up invention as a career, the Civil War was past. The energies of the country had been released for a burst of business enterprise, of speculation, of material progress generally. Edison had a faculty of making things work, of bringing things to pass, of overcoming obstacles thought to be insurmountable. His ingenuity and boldness of attack were exactly what capitalists and public were looking for—capitalists because he showed the way to profitable investment; public because he did "stunts" with things near to its everyday life. He gave Bell's telephone a real transmitter and thus made it

". . . speak out loud and bold."

His name for years was placed on all Bell telephone sets. With his electro-motograph he furnished to Morse's telegraph a new sounder requiring neither a retractile spring to withdraw an armature from an electro-magnet nor any electro-magnet at all. He thereby delivered the telegraph from the menace of Jay Gould, who controlled the Page patent on a retractile spring. Using the principle of this same electro-motograph, he provided a loud-speaking receiver for the telephone. He thus established the fact that Bell's receiver was not indispensable in telephony any more than Page's retractile spring was in telegraphy. Such a man naturally convinced financiers that he was a handy person to have around when they wished to escape suits for infringement or to stake their

[53] W. P. Warren, in the "Century" for July, 1911; p. 416.

investments on schemes that were likely to be "practical" from the dividend-paying viewpoint. The public began to regard him as a marvel and to call him "the Wizard" —a title bestowed on him by the newspapers.

Then he invented the phonograph, by which he was the first mechanically to reproduce human speech and song. The phonograph aroused prodigious general interest. Edison was now looked upon as a "wizard" indeed. To be applied to several "practical" uses, the phonograph had only to be developed. That development was postponed to make way for Edison's advance against a fresh impossibility—the subdivision of the electric current. From the invention-factory at Menlo Park issued the incandescent electric lamp, dynamos to supply it with current, and a long series of auxiliary devices through which the central-station system of incandescent electric lighting was organized and rendered commercially possible. On this spacious accomplishment was based a vast new industry. This industry in turn lent the first real impetus to the new profession of electrical engineering; and from it grew manufactures of great variety and wide extent. Green pastures opened in every direction for capital stock. So impressed was the public that many persons became persuaded that Edison had invented electricity!

The record is not in doubt. Edison was working, as he frankly professed, in applied science. A tendency has grown up to criticise him because he was not a disinterested seeker after truth, was not concerned with pure scientific research, was not content to "scorn delights and live laborious days" for the sake, primarily, of adding to the sum-total of scientific knowledge. Such criticism is rather beside the mark, but it may help to define Edison's position more clearly.

In 1922 Edison visited the General Electric works in Schenectady, New York. It was no wonder, editorially commented "The New York Times," that he received a "clamorous and enthusiastic welcome." [54]

"Mr. Edison," continued the "Times," "is a great inventor and exploiter of inventions, and but little more than incidentally a 'man of science.' His efforts always have been aimed directly at the doing of things that needed to be done—things the doing of which would be immediately and largely profitable. That was his natural bent, and properly he followed it, to his own and the world's great advantage. If what is called 'pure science'—the search for new truth and new knowledge for their own sakes—ever has interested him, it has not been for long or deeply.

"As he put it himself, men like Langmuir, Whitney and Steinmetz have traveled far in fields he only entered because they had more time. But they didn't; he, like everybody else, had all the time there was. He chose to use it for other purposes, and he has his reward, just as they have theirs." . . .

It should be added that just as Edison is not lacking in appreciation of "pure science," so he has enjoyed the admiration and respect of such men as John Tyndall, Sir Oliver Lodge, Hermann von Helmholtz, Louis Pasteur, Lord Kelvin, C. P. Steinmetz—men, that is, pre-eminently qualified to understand and value his achievements and services. Kelvin, one of the greatest physicists of his own or any time, was outspoken in his praise of Edison's work, with which he kept closely in touch. Edison, on the eve of his sixty-ninth birthday, was guest of honor at a banquet tendered by the Illuminating Engineering Society (New York); and in a speech deliv-

[54] October 20, 1922.

ered on that occasion, Steinmetz said: "He has done more than any other man to promote the art and science of electrical engineering."

The suggestion has occasionally cropped up that Edison owed much to the ideas of his assistants and that the fact has never been properly acknowledged. As to this, we have the testimony of men closely associated with him at various times. In their work on Edison, Dyer and Martin say:[55] ". . . Edison always stood shoulder to shoulder with his associates, but no one ever questioned the leadership, nor was it ever in doubt where the inspiration originated. The real truth is that Edison has always been so ceaselessly fertile of ideas himself, he has had more than his whole staff could ever do to try them all out; he has sought co-operation, but no exterior suggestion."

Referring to the autumn of 1880, when he was a new man at Menlo, E. G. Acheson wrote:[56]

"Mr. Edison was at this time working upon an electric meter to be used in connection with central station distribution. I became acquainted with the requirements of the case and the urgent need of such an instrument. What appeared to be a happy thought occurred to me for the method and design of a meter. I made a drawing of my proposed instrument, and the next time Edison came into the room I showed it to him. He seated himself on a high stool at the drawing table, put his arms on the board, and his head, face down, on them, and seemed lost for some time in thought. After some minutes he raised his head and addressing me said, 'I do not pay you to make suggestions to me. How do you know but

[55] I, pp. 324–325.

[56] "My Days with Edison," in the "Scientific American" for February 11, 1911; p. 142.

that I already had that idea, and now if I use it you will think I took it from you.' I assured him that I considered anything I could produce while in his employ and pertaining to his interests, belonged to him; that my thinking on those lines was due to my being in his laboratory and cognizant of his needs and lines of work. He made a test of my meter scheme, and notwithstanding it looked so feasible, it proved a failure." . . .

W. S. Mallory, at the time he was connected with Edison's ore-milling venture, emphatically stated: "I want to say, and I know whereof I speak, for I have been with him night and day for several years, that ninety-nine per cent. of the credit of all the invention and new work of this establishment is due personally to Mr. Edison. I have heard it stated that Mr. Edison is an organizer who uses the brains of other men. Nothing could be further from the truth than this." [57]

After selling his electro-motograph rights to Orton of the Western Union for $100,000, Edison specified that the amount should be paid to him at the rate of $6,000 a year. His reason for this arrangement was that it would safeguard him against staking the lump sum on a new invention. Your business man would probably exclaim, "Why, he was only getting interest for the use of his money!" But if business men have criticised Edison's business ways, no less has Edison from his viewpoint criticised the ways of business.

Here and there, in tracing Edison's story, one has illuminating side-lights on a certain type of American "big business" ethics. For example there is the episode of Jay Gould and the Automatic Telegraph company. Briefly, Gould contracted to purchase the Automatic interests for

[57] Theodore Waters, "Edison's Revolution in Iron Mining," in "McClure's Magazine" for November, 1897; p. 92.

$4,000,000. He appropriated the patents and properties of the Automatic company—the patents including those connected not only with the automatic but also with the duplex and quadruplex. Then he repudiated his contract. "I lost," said Edison, "three years of very hard labor."[58] For about thirty years the matter dragged through the courts; and at the end the plaintiffs won but a hollow victory.

"Wall Street" and its methods have had faint praise from Edison. When he engaged Charles E. Chinnock to put the Pearl-street central station on a commercial basis, he personally guaranteed Chinnock $10,000 in the event of success. Chinnock made good, and Edison duly paid over the $10,000. Afterward, the Edison Electric Light company, when Edison suggested that it reimburse him for this amount, said it was "sorry" but declined to pay—this in spite of the fact that the money had been expended in behalf of the company, contributing toward the establishment of the Edison system, which the company controlled. "Wall Street sorry" was how Edison characterized this attitude.[59] He has also related that "one of the wealthiest men in New York" tried to induce him to "sell out" his associates in electric lighting—a bribe of $100,000 being vainly dangled.[60] For such duplicities of business he has had a hearty contempt.

Of the treatment of inventors by capitalists, he once said:

". . . The working out or commercializing an invention costs money, but that is usually done by the company that makes money out of it. What they need is to do something so the inventor can make money out of his in-

[58] See D. and M., I, 163–167.
[59] *Ib.*, I, 436.
[60] *Ib.*, II, 664.

vention and not have it all go to the company that buys up his rights. If an inventor could make $50,000 out of his first invention, he would turn right around and put that money into making other inventions—some that might be worth millions to the public. That is a characteristic of a true inventor. Inventors have insufficient means to fight a patent case with the present methods of procedure in the courts, and it amounts to a nullification of the patent as far as the inventor is concerned. There are many corporations that know this and make a business of appropriating every patent of value. Sometimes a competing company will give the inventor enough to pay a little on his debts and fight the pirating company, but the inventor gains nothing if they are successful. I think courts ought to protect the inventor against business men." . . .[61]

For business routine Edison has never had a liking. In Newark, according to him, when first he was manufacturing stock-tickers, he jabbed bills receivable on one hook, bills payable on another, and allowed all notes to go to protest. This delightfully simple method functioned, he says, to everybody's satisfaction. But in a fatal moment he acquired a book-keeper. At the end of three months the book-keeper reported a profit of $3,000. Edison celebrated this with a supper to some of the men. Two days later the book-keeper rendered a revised statement showing a loss of $500. This made the supper appear a bit premature—but only temporarily, for a re-revised statement proclaimed a profit of more than $7,000. Small wonder if Edison looked fondly back to his little system of two hooks and protested notes! [62]

61 W. P. Warren, "Edison on Invention and Inventors," in the "Century Magazine" for July, 1911; p. 419.

62 D. and M., I, 135.

At Menlo he would neglect his correspondence for days at a stretch. Sometimes he would be asleep when the business office most urgently wished to confer with him. But when he was accessible, he would quickly fasten upon the substance of the details presented to him and give his directions as to what should be done.

For business in the broader sense he has, of course, shown great capacity. He saw a future for electric traction though few business men could see it. As a manufacturer of essential parts for his electric-lighting system, he developed an undertaking of high commercial value. After he removed to West Orange, he built up a series of Edison enterprises under his personal supervision and carried them on with administrative skill. The collapse of his big ore-milling scheme was due to natural causes that could not have been foreseen and the effect of which could not be avoided. His energy in tackling new problems—as, for example, the making of synthetic phenol—has been striking.

He has gained wealth, but doubtless he might have gained far more had it not been that wealth for its own sake does not appeal to him. Back in 1879, a reporter said to him, "If you can make the electric light supply the place of gas, you can easily make a fortune." Edison answered, "I don't care so much for a fortune" [63]—and he meant it. Prof. F. W. Taussig, the well-known economist, has written that although "the love of distinction and the more material self-regarding motives" have also clearly moved Edison to some extent, yet the man is chiefly possessed by "an instinct of workmanship or continuance." "We are so immersed," adds Taussig, "in the present individualist system that we can hardly con-

[63] See H. C. Brown, "The Book of Old New-York" (New York, 1913); p. 247.

ceive how we should act under conditions totally different. Prediction might be expected to be easier as regards those rare persons, like Mr. Edison, in whom some particular bent appears with extraordinary strength. Yet even here we cannot be sure. What sort of things would he have worked at in a collectivist society, and would his services have been greater or less? To these questions we can give no convincing answers." [64]

Edison's gospel of work and his disrelish of mere money-making for its own sake have held valuable lessons for his countrymen—and still hold. The same is true of his firm insistence upon high standards in design, materials, workmanship, and marketing. He has never knowingly sacrificed quality. It has been his pride to see that his signature trade-marked upon a product was a guarantee of excellence. He has not sponsored contraptions. The improvement of a thing is to him as attractive as the original invention of it. When he has felt that an Edison device was defective under conditions of actual use, he has withdrawn or retired it. It is rather an open secret that even within the Edison sales organizations murmurs have been heard that the "Old Man" was too much concerned with making things good. In a civilization whose modern factory system has turned out so much of the sham, the shoddy, and the inferior, Edison's example has been salutary.

Yet another service Edison has rendered, if we may accept the expert testimony of Doctor Maclaurin:

"All the world is indebted to Mr. Edison, but the portion of it that is under special obligation is the educational world, particularly the schools of technology. It is not merely that he has helped them by

[64] See the "Quarterly Journal of Economics" for August, 1912; pp. 776–781.